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Indira Gandhi Canal: Afforestation and its Impact on Forest Cover in Rajasthan (India)

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Abstract: ***Study area is located in the state of Rajasthan, which is situated in the North western part of the country. Rajasthan covers a geographical area of 342239 Sq.km., which is ten percent of the total geographic area of the country. The western part of the desert is barren and arid, through which Indira Gandhi canal flows. This barren arid land, which is known as Thar desert is characterized by severe hot and arid climate along with desertification. During summer season, weather is extremely inhospitable with high temperature and low humidity, along with high speed wind, sometimes dust storms. Dust storm, along with wind erosion and deposition is the characteristic feature of the western Rajasthan. Therefore, to combat desertification, afforestation programs have been taken up in different phases in Indira Gandhi canal command area, which has affected the overall forest cover in the state, especially western part of Rajasthan. The project has been designed to fulfill different objectives which includes the drought proofing, improvement in micro-climatic conditions, rehabilitation, protection of animal wealth, extention of green land. Trees like Dalbergia sissoo, Prosopis cineraria, Tecumella nudalta, zizyphus jujuba, Acacia Senegal, Acacia nilotica, etc. have been planted along canal, roadside and in different Abadies in the canal command area. In an extreme arid area of western Rajasthan, afforestation has reduced wind velocity and the dust storm. Afforestation of shifting sand dunes not only eliminated hazards but brought about durable benefits through improvement in soil fertility and soil moisture regime, which has ultimately led to increased agricultural productivity. Agricultural land use has been changed from subsistence to intensive form of agriculture, as well as net sown area has also increased, which means that there is a desire among inhabitants to grow economically beneficial crops. Above all there has been an increase in forest cover according to the last assessment in the year 2019. The state forest cover has been marginally increased as compared to the assessment year 2017. This increase in forest cover may be only due to afforestation in the canal command area, because different government policies, like Harit Rajasthan, which aimed to plant 25 lakh trees in the state over 61000 hectares of the forest land remained just a numbers on paper.***

Keyword: Rajasthan, Indira Gandhi Canal, IGNP, Western Rajasthan, Afforestation, Forest Cover

1. Introduction

The Indira Gandhi Canal the longest canal of India and world's one the most gigantic project, which aims to transform desert waste land into agriculturally sustainable area as well as to reduce the desertification. Indira Gandhi Canal was started with multi-pronged objectives, like improvement in environmental conditions, drought proofing, protection of animals from drought, providing drinking water, both for animals and human beings as well as generation of employment opportunities by means sustainable agriculture. It starts from the Harike Barrage at Harike, a few kilometers below the confluence of the Satluj and Beas rivers in Punjab and provides irrigation facilities in the Thar Desert, located in the north western part of the state of Rajasthan. Indira Gandhi Canal was previously known as the Rajasthan Canal. After the assassination of Prime Minister Indira Gandhi it was renamed as Indira Gandhi Canal on 2, November, 1984.The idea of bringing the waters from the Himalayan Rivers was conceived by an hydraulic engineer, Kanwar Sain in the late 1940s who proposed that 2,000,000 ha. (20,000 Sq.Km.) of desert land in Bikaner and the northwestern part of Jaisalmer could be brought under irrigation. In 1960, Indus Water Treaty was signed between India and Pakistan, which gave right to use waters of three Himalayan rivers –the Satluj, Beas and Ravi.

The Indira Gandhi Canal Project was conceived in October, 1948 and construction work was commenced in March, 1958. The first water was released by Late Dr. Radha Krishnan, the then Vice President of India on 11th October, 1961 at Naurangdesar. On 1st January, 1967, water reached Mohangarh, afar end village in Jaisalmer district. The journey is still on towards its ultimate destination i.e., Gadra Road in Barmer district. The project now envisage to provide irrigation facility to 1869000 ha. of land spreading in the districts of Ganganagar, Hanumangarh, Bikaner, Jaisalmer, Jodhpur, Barmer and Churu and utilize 9362 M.cum. of water out of 10608 M.cum. allocated to Rajasthan from Ravi and Beas rivers. Waters of both Ravi and Beas are picked up at Harike Barrage near International border with Pakistan.

The construction work of canal was taken up in two stages. Stage-I of the project starts from the Harik Barrage, covering 204 km. long feeder (170 Km. in Punjab and Haryana and 34 Km. in Rajasthan), 189 kms long Main Canal, with a discharge capacity of18500 at Harrik Barrage head. Out of 3400 Km, 3146 kms., long distribution system has been completed in 1998. Stage-I has five flow and one lift canal. The Stage-II of the project starts immediately downstream of 189 km. of the main canal and extends upto Gadra Road in Barmer district. It consists of 256 km. long Main Canal and 5780 km. long distribution systems.Apart from the Irrigation and Region Development Program, Indira Gandhi Nahar Project (IGNP), conducted afforestation in the selected areas in Stage I and Stage II of IGNP.

Table 1: District wise Area Covered by the Project

District	Culturable Command Area (000 Ha.)	Area covered by the Project (000 Ha.)		
		Stage-I	**Stage-II**	**Total (% of Col. 2)**
Sriganganagar	2,063.4	180	-	443 (21.46)
Hanumangarh		198	65	
Bikaner	2,724.4	175	402	577 (21.18)
Jaisalmer	3,840.1	-	648	648 (17)
Barmer	2,838.7	-	62	62 (2)
Churu	1,683.0	-	66	66 (4)
Jodhpur	2,285.0	-	66	66 (3)
Total	15,434.6	553	1316	1869 (12.1)

Source: Environmental Impact of Indira Gandhi Canal, IGNM, Jaipur, 1997

According to table 1 district-wise area covered by the project, reveals that, the highest culturable command area has been recorded by Jaisalmer with a total command area of 3840.1 thousand hectares, which is followed by Barmer (2838.7 thousand ha.) and Bikaner (2724.4 thousand ha). According to the report on Environmental Impact of Indira Gandhi Canal, Jaipur, 1997.Jaisalmer with highest culturable command area recorded 648000 ha area covered by the project in stage II, which is just 17 percent of the culturable command area of Jaisalmer, whereas Barmer recorded only 62000 ha area covered by the project in stage II, which is just 2 percent of the total culturable command area of Barmer. Apart from these two district, Bikaner recorded 175000 ha. in stage I and 402000 ha. area in stage II, covered by Indira Gandhi Nahar Project, which is 21.18 percent of the total culturable command area of Bikaner, second highest area covered by the project. Sriganganagar and Hanumangarh combined together recorded 443000 hectare, covered by project, which is 21.46 percent of the total culturable command area of 2063.4 thousand hectare. Out of the total culturable command area of 15434.6 thosuand hectare only 12.1 percent i.e., 1869 (12.1 percent) thousand hectare of area has been covered by the project

Table 2: Culturable Command Area in (M.ha.) IGNP Stage I AND Stage II

Name of Districts	Stage I	Stage II	Total
Ganganagar	190		190
Hanumangarh	180	92	272
Bikaner	183	412	595
Churu		115	115
Jaisalmer		652	652
Jodhpur		77	77
Barmer		60	60
Total	. 553	1.410	1.963

Source: Gupta et.al. (2002)

According to table 2 total culturable command area is 1.963 million hectare, out of which 1.410 million hectare is located in stage II and 0.553 million hectare is located in stage I. Out of 1.963 M.ha, Jaisalmer recorded highest culturable command area with 652 million hectare, which is followed by Bikaner (595 M.ha) and Hanumnagarh recorded 190 million hectare, whereas, Barmer recorded the lowest culturable command area, which is only 60 million hectare.

Project Area (Study area)

Rajasthan is the largest state by area in India and is located between 23°30′ and 30° 11′ North latitude and 69° 29′ and 78° 17′ East longitude. The project area lies along the international border with Pakistan in the famous Thar desert of Indian subcontinent. The Thar desert occupies 19.84 million hectares or 58% of the geographical area of Rajasthan state and 6% of the geographical area of India. Substantial portion of the project area is covered with low to medium height dunes. The area is devoid of natural drainage except river Ghaggar, flowing through Hanumangarh and Sri Ganganagar districts and a small stream called “Kakni” in Jaisalmer district. According to the Throntwaite’s method of climatic classification, the project area may be broadly classified as arid plain. During summer season intense heat along with very strong winds is experienced. This exceptionally strong wind flowing from South-West to North-East, causes wind erosion as well as blows sand. The rainy season lasts for a very short spell between mid-July to first week of September.

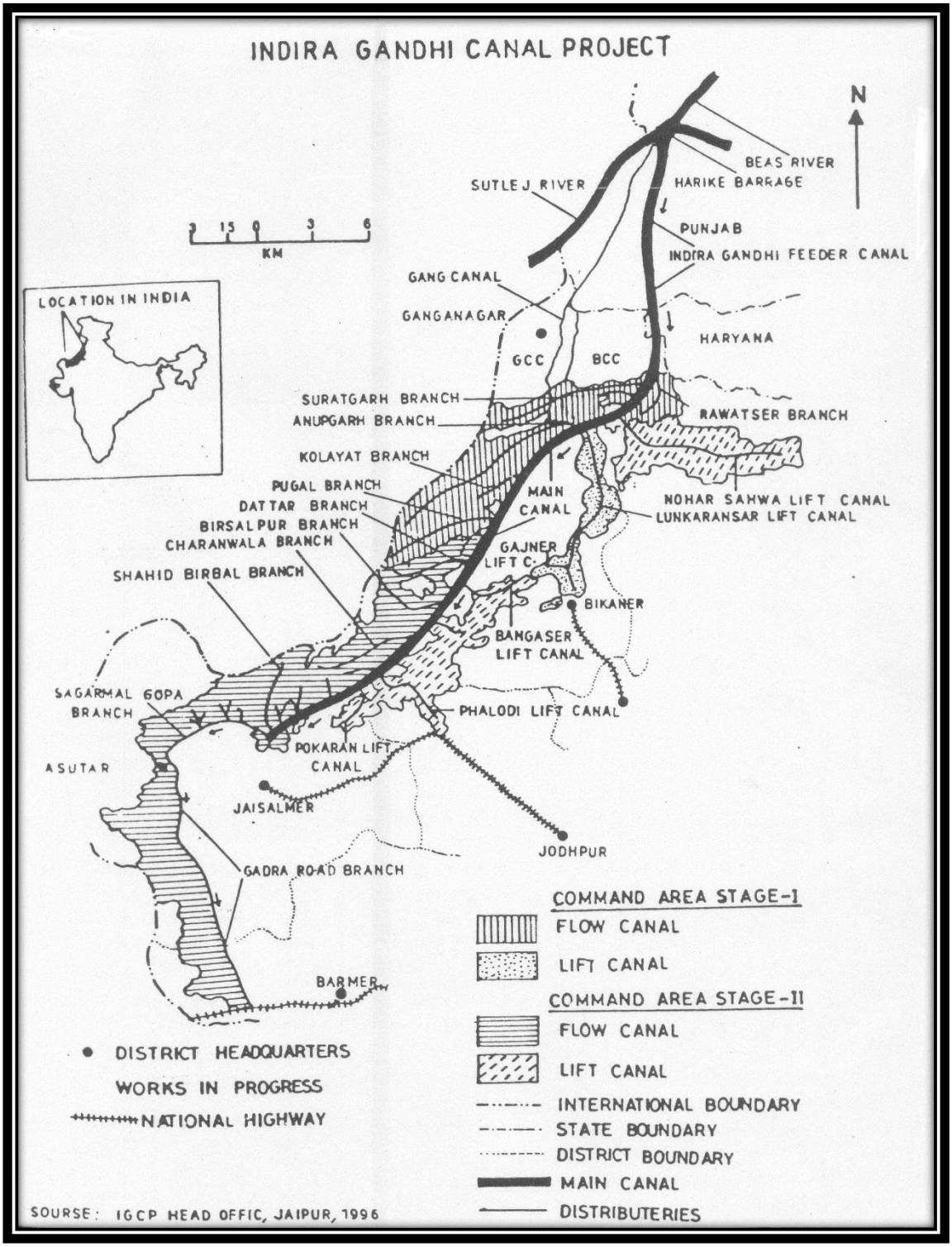

Figure 1

The study area is thinly populated and the main source of livelihood of the people, before the introduction of the Indira Gandhi Canal, was rearing of cattle for ghee, wool and leather and the agricultural activities were entirely depending on monsoon rainfall.

Objectives of the study

To assess the afforestation program in Indira Gandhi Canal Command Area and to find out it's impact on forest cover and forest related aspects of Rajasthan. It also involves the comparative study of forest cover between Rajasthan and Western Rajasthan, through which Indira Gandhi Canal flows.

Database and Methodology

The research paper has been designed to understand the afforestation programs in the Canal Command area, therefore it is primarily based on the secondary sources of data, which has been gathered from the Head Office of Indira Gandhi Canal Project,Jaipur, District Head Offices, Regional offices, Canal Command Area Development offices, Forest Department of Rajasthan, State of Forest Report, as well as other published research works. After

collecting information from different secondary sources, the relevant data has been tabulated and analyzed with the help of cartographic techniques, and has been presented in the form of qualitative statements

Objectives of Afforestation

1) To check the dust storm and drifting of sand by reducing wind velocity
2) To check the silting of canal due to drifting sand.
3) To improve the ecosystem and micro-climatic conditions the region.
4) To meet the demands of fire wood, timber and fodder for the existing as well as projected population of the districts through which Indira Gandhi Canal flows.
5) To create employment opportunities for the poor and landless villagers.
6) To enhance the aesthetic beauty and landscape of the area.
7) To develop the forest based industries.
8) To reduce the migration of livestock during drought years and to increase its productivity
9) To protect agriculture from hot drifting winds.

Vegetation:

Western Rajasthan is characterized by the desert topography, sandy soils and sand dunes. At places bare rocks are exposed but whole of this region is largely sandy. Few small trees can be observed here and there and the vegetal cover is very thin. Large areas are covered with scrubs, which are thorny and have a stunted growth. This is the first time, that an irrigation project in the desert has included, forestry in its project plan, therefore the canal side afforestation have been a success which includes following species.

	Common name	**Botanical name**
1.	Shisham	*Dalbergia sissoo*
2.	Khejri	*Prosopis cineraria*
3.	Rohida	*Tecomella undulate*
4.	Ber	*Zizyphus jujuba*
5.	Kumath	*Acacia Senegal*
6.	Subabool	*Leucaenia leucocephala*
7.	Jal	*Salvadora persica*
8.	Babool	*Acacia nilotica*
9.	Phog	*Calligonum polygonoides*
10.	Farash	*Tamarix spp*.
11.	Safeda	*Eucalyptus camaldulensis*
12.	Siras	*Albizzia lebbeck*
13.	Ardu	*Allanthus excelsa*
14.	Shehlot	*Morus alba*

Before the project, the arid project area was passing through the state of overgrazing and over exploitation and vegetation was gradually reducing. Due to this, the ecological balance of the region was disturbed leading to progressive degradation of its resources. But after the introduction of canal, most dense forest of Rajasthan has been created in this arid region. Afforestation programs during the year 1997-98 with the assistance of CAD are given in Table-3.

CAZRI, suggests that afforestation of shifting sand dunes not only eliminates hazards but brings about durable benefits through improvement of soil fertility. Afforestation in more than 172,463 ha of the project area, apart from reducing the hazards of wind erosion and shifting dunes, has improved the microclimate, soil fertility and the yield of various crops which has also resulted in the reduction of soil erosion and silting of canals andalso the extraction of ground water.

According to table 3 afforestation under OECF project reports, that the afforestation along canals, roads and settlement has been carried outup to March 1998. Till March 1998, canal side plantation were carried out upto 11060 RKm; whereas, road side plantation were done to the tune of 93 RKm, and block plantation were aimed to achieve 435 ha. under afforestation but only 378 ha. were brought under afforestation. Under sand dune stabilization 6853 ha. area were targeted to be brought under afforestation, but 6749 ha. area were brought under afforestation, which is little less than the target set by the OECF project. If we see the afforestation under pasture development, only 800 ha. were brought under afforestation, out of 6853 ha., which the OECF aimed to brought under afforestation.

According to table 3, afforestation in Stage-I under CAD remained successful as compared to stage II because, not a single hectare of land could be brought under afforestation. Till March, 1998, afforestation were done over 200 Rkm along canal side, whereas 200 ha were brought under Block plantation. Apart from the above, 800 ha. were brought under sand dune stabilization.

Table 3: Afforestation by CAD during 1997-98

S. No.	Item	Unit	Target	Achievement upto March 98
A) Afforestation (OECF Project)				
1.	Canal Side Plantation Advance Action	RKM RKM	11734 4400	11060 450
2.	Road side Plantation	RKM	845	930
3.	Block Plantation Advance Action	Ha. Ha.	435 300	378 88
4.	Sand dune stabilization	Ha.	6853	6749
5.	Pasture development Advance Action	Ha. Ha.	2572 600	800 500
6.	Farm Forestry Advance Action	No. in lacs No. in lacs	9.00 1.74	8.57 4.50
B) Afforestation (CAD Stage-II Project)				
1.	Road side Plantation	RKM	486	NR
C) Afforestation (CAD Stage-I Project)				
1.	Canal side Plantation Advance action	RKM RKM	200 200	200 120
2	Block Plantation Advance Action	Ha. Ha.	200 350	200 250
3.	Sand dune stabilization Advance Action	Ha. Ha.	800 900	800 900
4.	Farm Forestry Advance Action	Lac. N0. Lac No.	9.00 9.00	9.56 7.50

Source: Indira Gandhi Nahar Project, Govt. of Rajasthan, Annual Report, 1997-98.

Afforestation in Stage-I

Forest plays a key role on the economy of an irrigation project and especially in an area like, IGNP Command Area, which is devoid of vegetative cover and is affected by wind erosion. The afforestation activity in stage I was started in the year 1962, but it was taken up on large scale from 1974 under different phases. The afforestation component is vital

for mitigating the harsh environment in the project area and will also reduce maintenance cost of the canal and road. It was in this context that experimental afforestation was started during the period 1962 to 1966 to evolve suitable technique and to find suitable species for afforestation. This work was done under the program of the IGCPCA. The program has been later financed by the World Food program during the period of 1971 to1975. It was further taken in different phases with the assistance received from World Bank, WFP, DDP, DPAPIWLDPJRY and CAD etc., for the Tree Plantation Program.

Table 4: Progress of afforestation work in I.G.N.P

Stage- I from 1988-89 to 1991-92					
Name of the work	Programme				Total
	CAD	DDP	IWLDP	JRY	
Canal side plantation	466(1398 RKm)	232(698 RKm)	172(430 RKm)	33(100 RKm)	903(2626 RKm)
Road side plantation	----------	15 (30 RKm)			15 (30 RKm)
Village fuel wood plantation		87.5			87.5
Block plantation	377	45	97		519
Silvi pastoral		250			250
Total	1330	1800.5	543	33	3706.5

Source: The Research Journal of Social Sciences, Volume 1, Issue 11, April, 2008

According to table 4, a total of 3706.5 ha land were brought under afforestation from 1988-89 to 1991-92 in stage-I. Out of 3706.5 ha. Afforestation were carried out on 1330 ha. of land under CAD program, whereas, 1800.5 ha were afforested under DDP program. Apart from this, 543 ha. of land were afforested under IWLDP program, whereas only 33 ha. of land were afforested under JRY program. It is evident from table 4 that 903 ha land were brought under canal side plantation, which accounted for 2626 RKm., whereas only 15 ha. (30 RKm) were brought under Road side plantation. Afforestation program were more focused on sand dune stabilization, which accounted for 1932 ha. of land, because moving sand dunes, due to high speed wind is a menace in the arid land of Indira Gandhi Canal Command Area. Apart from sand dune stabilization 519 ha. of land were brought under Block plantations and village Fuel wood plantation were carried out on only 87.5 ha. of canal command area.

Since the inception of afforestation program in IGNP Command Area, according to table 5, a total3706.5 RKm.has been afforested up to 1992 and about 114463 ha. area has been planted upto 1997, under various schemes which are as follows:

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Plantation along canals, roads and Abadies has been carried out so that the intensity and impact of blown sand could be reduced. Pasture development and sand dune stabilization work have been carried out so that fodder could be made available to the livestock of the adjoining villages as well as the migrating flocks. Fuel wood plantation has been carried out so as to meet the every needs of rural population. Canal side plantation were mainly Acacia nilotica (Babool), Dalbergia sisso (Shisham), Acacia senegal (Kumath), Prosopis cineraria (Khejri), etc. According to table 6, total area under different categories of plantations and area covered under Stage I is 114463 ha. Out of the total covered area, 11703 ha. has been brought under canal side plantation, whereas, road side plantation has been carried out on 2582 ha. of land. Apart from this fuel wood (Abadies) plantation has been carried out on 5270 ha. of land, but the main thrust has always been towards sand dune stabilization and pasture development, and due to this fact, it covered an area of 94908 ha., which is much larger than any other afforestation program in the Indira Gandhi Canal Command Area. The space between the plants were generally 5x3 mt. There were 15 to 25 rows each sides on Main Canal, while 5 to 10 on branches and 3 to 5 on distributaries.

Table 6: Different Categories of Plantations and Area Covered Under: Stage-I

S. No.	Type of plantation	Area covered (ha.) Stage-I
1.	Canal Side Plantation	11,703
2.	Road side Plantation	2,582
3.	Sand dune stabilization and Pasture development	94,908
4.	Fuel Wood (Abadies) Plantation	5,270
	Total	114,463

Source: Environmental Impact of IGCP, IGNM, Jaipur, 1997

Afforestation in Stage-II

It was started in 1984 to 1986 on small scale which was speeded up from 1987 on large scale.Due to difficult geo-climatic condition in Stage II, plantations were carried out in

much wider strips on either sides of the Indira Gandhi canal. Afforestation were also carried out at a closer spacing, because of high speed winds which causes sand deposition in canal. Because of lesser rainfall in Stage II plant saplings were irrigated by means of diesel engine pumping sets and only indigenous species, like Acacia senegal, Prosopis cineraria, Zizyphus jujuba, Salvadora persica and Acacia nilotica were planted.

World Food Program funded afforestation work in Stage II, which were carried out from 1985-86 to 1988-90 with the help of CAD and DDP. According to Table 7 a total of 21101 ha of land were brought under afforestation from 1985-86 to 1989-90. Under this program main focus was on canal side plantation, because of deposition of sand in canal due to blowing winds and 7317 ha. of land were brought under canal side

Table 7: Progress of afforestation works in I.G.N.P. Stage II

From 1985-86 to 1989-90	
Name of the work	Area in Hact.
Canal side plantation	7317 (21951 RKm)
Road side plantation	270 (540 RKm)
Block plantation	3153
Sand- Dune Stabilization	8361
Pasture Development	2000
Total	21101 Hect.

Source: The Research Journal of Social Sciences, Volume 1, Issue11, April, 2008

Plantation. Apart from this sand dune stabilization program were carried out on 8361 ha. of land, as sand dune drifting is a greatest problem in arid region of Rajasthan, therefore to stabilize sand-dunes, windward side plantation has been adopted as it reduces the intensity of wind.

Table 8: Progress of afforestation program in I.G.N.P. Stage II
From 1990-91 to 1991-92

Scheme	Area Planted in Hectare				Total
	OECF	WFP & DDP	OECF	WFP	
Canal side plantation	1380	29	778		2187
Block plantation	200	975	442.5		1617.5
Sand- Dune Stabilization	450	1235	1756		3441
Pasture Development	300		635		935
Road side plantation			90		90
Environmental Plantation	18(20000 Plants)		19 (20800 Plants)		37 (40800 Plants)
Canal Bank Stabilization				20	20
Total	2348	2239	3720.5	20	8327.5

Source: The Research Journal of Social Sciences, Volume 1, Issue 11, April, 2008

According to Table 8, a total of 8327.5 ha of land were brought under afforestation under different programs like OECP, WF and DDP. It is evident from table 8 that out of 8327.5 ha, canal side plantation were carried out on 2187 ha. , whereas, 1617.5 ha.of land were brought under Block plantation. Apart from this main thrust of this project was on sand dune stabilization because of its multipronged effect on Indira Gandhi Canal and therefore, afforestation were carried out on 3441 ha. to stop the drifting of sand dune. Pasture development was also, one of the target under this program, therefore, 935 ha. of land were brought under pasture development, whereas, Road side plantation were carried out on 90 ha. of land and lesser importance were given to Environmental plantation, therefore, only 37 ha.of land were brought under it and 40800 Plants were planted.
The aim of afforestation in Stage II were shelterbelt plantation along roads and canals to protect them from windblown sand deposition, block plantation near villages for fuel wood, irrigated plantations for industrial purposes, farm forestry, sand dune stabilization, pasture development and plant protection.

Table 9: Afforestation Programme Under Stage-II: IGCPCA

Particulars	Units	Phase-I	Phase-II	Phase-III	Total
Shelterbelt along canals	Ha.	11760	6850	10346	28956
Shelterbelt along roads	Ha.	1000	1500	2200	4700
Village Plantation	Ha.	3000	3000	4500	10500
Industrial Plantation	Ha.	5000	5000	5300	15300
Sand dunes stabilization	No. of plants	45000	30000	42000	117000
Farm Forestry	Million	1.5	2.0	1.8	5.3
Total Expenditure	Rs. in million	256.20	277.90	268.7	802.80

Source: Office of the Rajasthan Forest Department, Jaipur, 1994

It is evident from table 9 that with the help of 802.80 million rupees, afforestation in the canal command area has taken place in three phases. A total of 28956 ha. of land has been brought under shelterbelt afforestation along canal, whereas, 4700 ha. has been brought under shelterbelt along road. It is also evident form the table that afforestation under sanddune stabilization has been carried out over 117000 ha. which is the largest area under afforestation in Stage II, whereas, 5.3 million farm forestry has been recorded under afforestation programs.

Japan with ODA loan carried out afforestation and pasture development in Indira Gandhi Canal command Area.Out of the total project cost of 9,258 million yen, the amount of 7,869 million yen, equivalent to 85% (the total of the foreign currency portion of 418 million yen plus the local currency portion of 7,451 million yen) was funded by the ODA loan. The remaining amount was funded by the capital of the executing agency. One of the important afforestation and development project under ODA loan from Japan has been completed in July, 2003. This project conducted afforestation program in the selected area in Indira Gandhi Nahar Project Stage II, which included 256 km main canal, 5000 km branch canal and 1012000 ha. irrigated area. According to this project 21400 ha. of land has been brought under canal side plantation in the year 2000, whereas, sand dune stabilization has been carried out on 34070 ha. of land. Apart from this, roadside plantation has been carried out on 1250 ha. and block plantation on 4248 ha. Pasture development program has been carried out on 5990 ha. of

land, whereas, 896 ha of land was brought under Environmental Plantation and 10 million trees were planted as agricultural forests.

Table 10: Output of the project
(ODA Loan, Japan)

Afforestation Scheme	Final Planned Levels in ha. (2000)
Canal Side Plantation	21,400
Road Sid Plantation	1,250
Block Plantation / Forest Preserves	4,248
Sand Dune Stabilization	34,070
Pasture Development	5,990
Agricultural Forests	10 million trees
Environmental Plantation	896 ha
Farm Forestry	50 locations

Source: Afforestation and Pasture Development Project along Indira Gandhi Canal Area, Field Study: July 2003, Japan's ODA Loan.

Because of the difficult geo-climatic conditions of stage-II, some changes have taken place in the technique of afforestation works, not followed earlier in Stage-I. More emphasis were given on indigenous species, closer spacing, and broader widths to be planted on both sides of the canal. Initially planting were done at 3x3 and 3x2meters but w.e.f 1990-91 plantation were done at 3x3 m. spacing and now it has been decided to plant at 4x3 m. The details of various scheme of plantation are given in the following paragraphs.

1) Shelterbelt plantation along canals

Shelterbelt plantation has been done along both sides of canals, to prevent sand deposition in the canals. Tall plants of suitable species such as *Dalbergia sisso* (Shisham), *Acacia nilotica* (Babool), *Eucalyptus camaldulensis* (Safeda), *Acacia tortilis* (Israeli Babool) and *Tamarix articulata* (Farash) are planted along canals in burrow pit area and on sand dunes. Eucalyptus are planted in patches where flow of irrigation water is possible. With effect from 1994-96 plantation is being done at 4x3 meters spacing. For the protection of plants from grazing, fencing of angle iron and barbed wire has beendone. At the time of plantation 830 plants/ ha. are planted but at the age of 6 and 12 years, two thinning are proposed, thus getting about 166 trees per hectare. It has been observed that sand deposition gas been considerably reduced within 2-3 yearsof plantation.

2) Shelterbelt plantation along Roads

The main objective of Shelterbelt plantation along roads is to protect roads from windblown sand deposition to keep transportation of vehicles unabated. When the roads passes through the un-stabilized sand dunes, planting has been done only on the windward side of the roads and six rows of plants are planted, whereas, leeward side remain unplanted, because of continuous dumping of blowing sand dunes. On both sides of the roads 3 to 5rows of plants are planted and the spacing is 4x3m. Species like *Dalbergia sisso, Acacia nilotica, Eucalyptus camaldulensis, Acacia tortilis* and *Tamarix articulate* are planted. Sowing of caster seeds and the planting of *Saccharum munja* (Moonja) are done along water course, so as to afford protection of plants from frost and also to act as a middle story in theshelterbelt.

3) Village plantation

Population has increased rapidly, with the provision of irrigation and expansion in settlement pattern, due to this, fuel wood are being depleted. Therefore to meet the requirement of fuel wood in the Indira Gandhi Canal Command Area, *Prosopis cineraria* (Khejri) tree and the *Calligonum polygonoides* (Phog) bushes have been planted. Besides improving the environment, these plantation will provide timber, fuel wood, fodder and fruits, close to the villages. Therefore village plantation has been done on the village lands (12.5ha) allotted to forest department in almost all new villages.

4) Sand dune stabilization

Because of the presence of sand dunes, about 28% of the land of Indira Gandhi Canal Project remain un-commanded by irrigation, These sand dunes are constant menace to the canal system and the irrigated farm lands. Therefore, to stabilize sand dunes and to meet the fodder requirements of the cattle breeds, a program of sand dune stabilization cum pasture development has been implemented. Bare and shifting dunes have been covered by brush wood and wind breaks, perpendicular to wind direction at approximately 6 m, intervals. Seed sowing of local shrubs like Pog, Khimp, Akra, Sevan grass, Senia etc. have been done along the mulch lines. Several plants like*Ziziphus mauritiana* (Ber),*Acacia tortilis, Prosopis cineraria, Prosopis julifera, Tecomella undulata* etc. have been planted at 4x3 m spacing with effect from 1994-95.

5) Farm Forestry

After the development of irrigation facilities, most of the land area in the IGCPCA have been under controlled agro-ecosystem for production of food grains and commercial crops. To preserve the diverse biotic environment of the region, it is therefore, essential to consider the relation between soil, vegetation and animal life.It has been partially accomplished by developing strips of trees interspersedwith cultivated fields. This scheme is being implemented to help farmers in planting trees on their farm boundaries Thus the Forest Department of Rajasthan has planted trees along the water course in the fields at a spacing of 5 meters. The plants generally supplied, included, *Eucalyptus camaldulensis, Dalbergia sisso, Zyziphus mauritiana, Acacia nilotica*, etc. Though, initially plants were supplied free of cost but now these are being issued on subsidized rates.

6) Pasture Development

Indira Gandhi Canal Command Area has been traditionally a pastoral area. A large chunk of uncommand sandy area has been utilized for fodder production. Therefore to achieve this target, more emphasis were given on sowing seeds of *Sevan grasses*. But satisfactory results could not be achieved due to erratic and meager rainfall. Therefore, to overcome this problem 6 months old *Sevan grass* seedlings are planted at 3x3 m. spacing. At suitable place 200 plants/ha of top feed species likeBer, Khejri, Ardu, *Acacia tortilis* etc. have also been planted.

Impact of Afforestation

One of the major impact of afforestation in Indira Gandhi Canal Command area is the improvement in forest cover in

western Rajasthan. Forest cover can be defined as all lands having tree canopy density of more than 10 per cent and area of one hectare or more in size, irrespective of their legal status and composition of species. According to 2019 report on Forest cover, the total forest cover of the country is 712249 sq.km, which is 21.67 per cent of the total geographical area. But if we see the total forest cover in the assessment year 2017; it was 708273 sq.km which comes to 21.54 of the total geographical area of the country. It is a good sign, that the forest cover in 2019 is slightly higher than the forest cover in 2017. But if we compare the forest cover of Rajasthan with India, we find it very discouraging, because it is much lesser than the country as a whole, with forest cover of only 16630 sq.km., out of total area of 342239 Sq. Km. in 2019, which is just 4.85 percent. If we see the forest cover of Rajasthan in 2017, we find that it was 16572 Sq.Km., which comes to 4.84 percent. It means there is an improvement of only 0.01 percent, from the assessment year of 2017 to 2019, which is again very discouraging.

If we classify the whole geographical area of Rajasthan into two broad categories of land cover, it can be classified in Forest cover and Non-forest cover. According state Forest Report 2001, forest cover can be further classified into dense forest cover and open forest cover. Dense forest cover includes lands with a canopy cover of 40 percent and above, whereas, open forest can be classified with a canopy cover between 10-40 percent. If we see the data regarding dense and open forest cover of Rajasthan, it is 4520 sq.km. and 11567 sq.km. respectively in the year 2011, but in 2019 dense forest cover increased to 11123 sq.km, whereas, open forest increased to 12210 sq.km. There is an increase of 146 percent in dense forest, whereas, there is an increase of only 5.55 percent in the open forest.

Growth of Forest cover 1999-2003

Table 11, percentage growth of forest cover from 1999 to 2003, shows that the highest growth was recorded by Churu with a growth rate of 520 percent which is followed by Ganganagar (465.51), Bikaner (262.50 percent) and Barmer (216.66 percent). If we go through all the districts of Rajasthan we find that all the six districts, namely Bikaner (262.50), Barmer (216.66), Churu (520), Ganganagar (465.51), Jaisalmer (60.49) and Jodhpur (47.05) recorded higher growth rate, as compared to other districts of Rajasthan, except Jhunjhunu (108.98), Nagaur (90.32), Sikar (78.64) and Tonk (45.76). If we classify Rajasthan, according to percentage growth of forest cover into Low

Table 11: District wise Percentage Growth of Forest Cover

S.N	District	1999	2003	% Growth	2011	% Growth	2019	% Growth
1	AJMER	168	266	58.33	277	4.13	305	10.10
2	ALWAR	1134	1212	6.87	1205	-0.57	1197	-0.66
3	BANSWARA	348	372	6.89	376	1.07	268	-28.72
4	BARAN		1082		1090	0.73	1011	-7.24
5	BARMER	54	171	216.66	172	0.58	290	68.60
6	BHARATPUR	620	236	-61.93	238	0.84	230	-3.36
7	BHILWARA	170	220	29.41	225	2.27	224	-0.44
8	BIKANER	56	203	262.50	208	2.46	256	23.07
9	BUNDI	418	441	5.50	453	2.72	557	22.95
10	CHITTAURGARH	1597	1675	4.88	1687	0.71	989	-41.37
11	CHURU	15	93	520	90	-3.22	82	-8.88
12	DAUSA						117	
13	DHAULPUR		421		419	-0.47	419	0
14	DUNGARPUR	221	250	13.12	252	0.8	302	19.84
15	GANGANAGAR	29	164	465.51	190	15.85	113	-40.52
16	HANUMANGARH						90	
17	JAIPUR	473	622	31.50	631	1.44	553	-12.36
18	JAISALMER	81	130	60.49	167	28.46	326	95.20
19	JALOR	141	205	45.39	208	1.46	268	28.84
20	JHALAWAR	301	393	30.56	397	1.01	436	9.82
21	JHUNJHUNUN	89	186	108.98	195	4.83	201	3.07
22	JODHPUR	68	100	47.05	93	-7	108	16.12
23	KARAULI						870	
24	KOTA	1663	616	-62.95	615	-0.16	547	-11.05
25	NAGAUR	62	118	90.32	119	0.84	147	23.52
26	PALI	618	614	-0.64	662	7.81	675	1.96
27	PRATAPGARH						1038	
28	RAJSAMAND		416		424	1.92	522	23.11
29	SAWAI MADHOPUR	1270	1289	1.49	1300	0.85	463	-64.38
30	SIKAR	103	184	78.64	193	4.89	193	0
31	SIROHI	800	885	10.62	916	3.50	912	-0.43
32	TONK	118	172	45.76	167	-2.90	165	-1.19
33	UDAIPUR	3254	3090	-5.03	3118	0.90	2758	-11.54
	TOTAL	13871	15826	14.09	16087	1.64	16630	3.37

Source: India State of Forest Reports of 1999, 2003, 2011 and 2019

Note: Total number of districts are 33 but the boundaries of new districts could not be delineated and their data has been given jointly with the parent districts.

(below 10 percent), Moderate (10.01 to 20 percent), High (20.01 to 30 percent) and Very high (above 30 percent). We find that there are five districts, namely, Alwar, Banswara, Bundi, Chittaurgarh and Sawai Madhopur recorded low forest growth, below 10 percent, whereas, only two districts, namely, Dungarpur and Sirohi recorded moderate growth between 10.01- 20 percent. Apart from seven districts only one districts, namely, Bhilwara (29.41) recorded high growth rate, whereas, there are

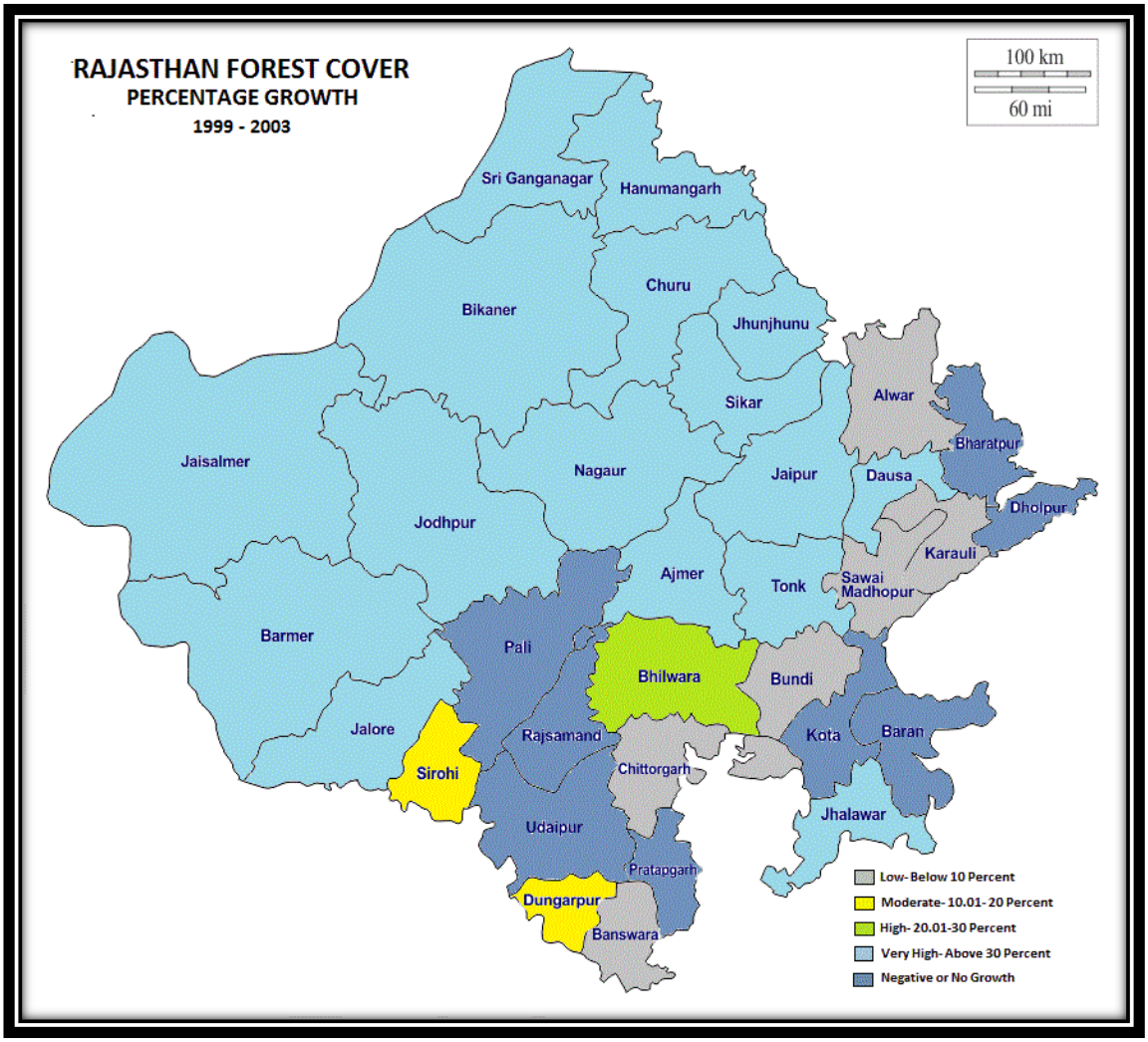

Figure 2

fourteen districts, namely, Ajmer, Barmer, Bikaner, Churu, Ganganagar, Jaipur, Jaisalmer, Jalore, Jhalawar, Jhunhunu, Jodhpur, Nagaur, Sikar and Tonk, recorded very high growth of forest cover above 30 percent. There are four districts, namely, Bharatpur (-61.93), Kota (-62.95), Pali (-0.64) and Udaipujr (-5.03), recorded low growth rate. Rajasthan as a whole recorded 14.09 percent, which is moderate. We can clearly observe from Fig.2 that all the districts, which are located in western Rajasthan, through which Indira Gandhi Canal flows, recorded very high growth rate of the forest cover, which may be attributed to the afforestation programs carried out in the Indira Gandhi Canal Command Area.

Growth of Forest Cover 2003-2011

During this period Rajasthan as a whole recorded a growth rate of 1.64 percent with a decline of 12.45 from 2003. Almost all the districts recorded a declining growth rate of forest cover. In spite of the fact that Harit Rajasthan scheme was launched in the year 2009, Harit Rajasthan envisaged planting of as many as 25 lakh trees in the state over 61000 hectares of forest land, but this program had to go a long way to give a fruitful result. Although the National forest policy envisaged at least one-third of the land under forests, but the state of Rajasthan recorded forest cover not more than 5 percent of the total geographical area because of its inhospitable climate and edaphic conditions, which is very less as compared to the national forest policy.

If we go through the percentage growth of forest cover among all the districts of Rajasthan, we find that Jaisalmer with a growth of 28.46 percent, recorded highest growth rate, which is followed by Ganganagar with a growth rate of 15.85 percent.

If we classify the districts of Rajasthan according to the percentage growth into low, moderate, high and very high, we find that there are twenty one districts namely, Ajmer, Banswara, Baran, Barmer, Bharatpur, Bhilwara, Bikaner, Bundi, Chittorgarh, Dungarpur, Jaipur, Jalor, Jhalawar, Jhunjhunu, Nagaur, Pali, Rajsamand, Sawaimadhopur, Sikar, Sirohi, and Udaipur recorded low growth of less than

10 percent, whereas only one district, namely, Ganganagar recorded moderate growth of forest cover between 10.01-20 percent. Apart fromthese twenty two districts there is only one district namely, Jaisalmer, recorded high growth of forest cover between 20.01 to 30 percent, whereas, rest of the districts, namely, Churu (-3.22), Dholpur (-0.47), Jodhpur (-7.0), Kota (-0.16) and Tonk (-2.90), recorded negative growth of forest cover. It is evident from the figure 3 that the high growth of forest cover has been recorded by the district through which Indira Gandhi canal flows.

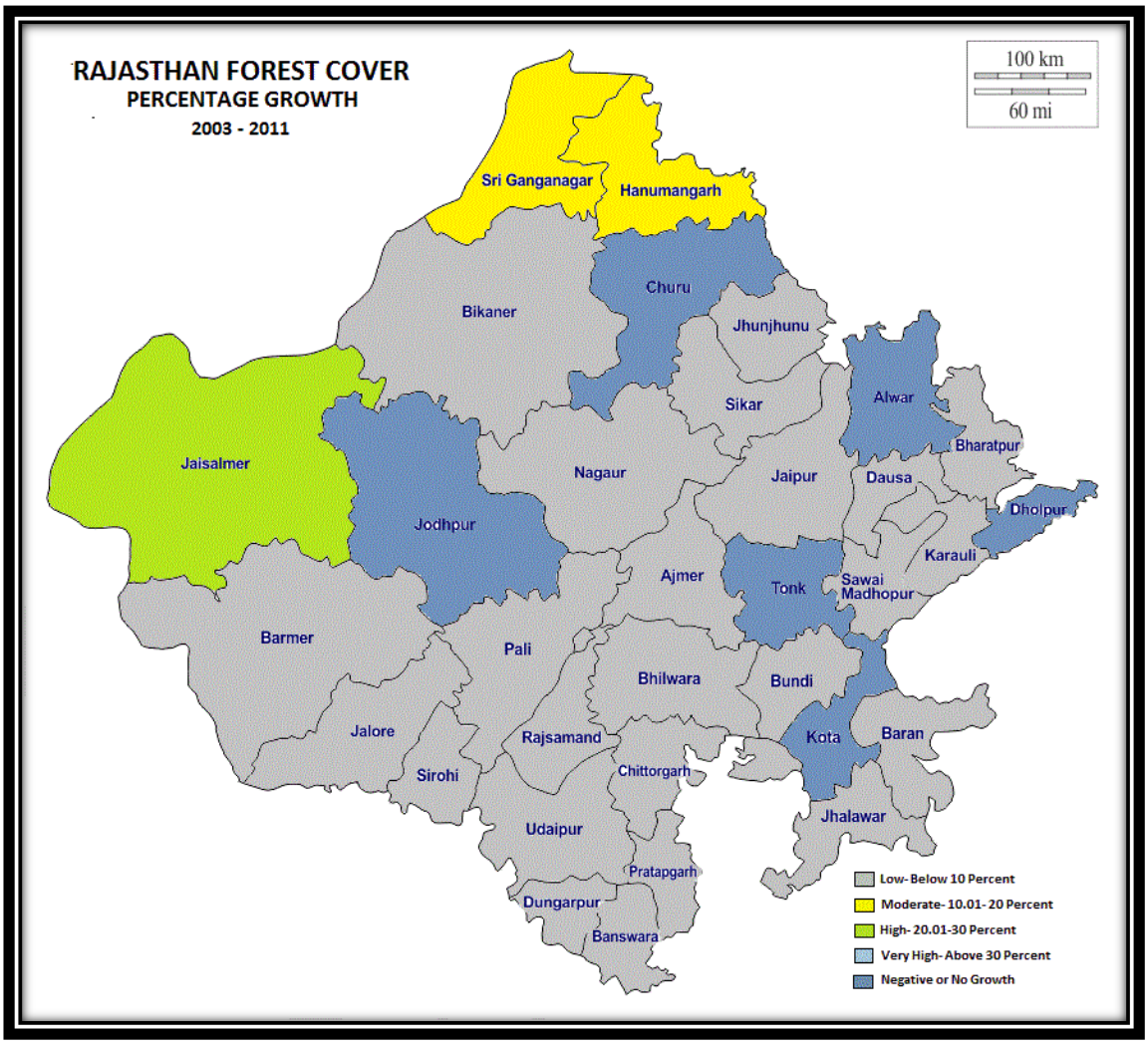

Figure 3

Growth of Forest Cover 2011-2019

Rajasthan as a whole recorded a growth of 3.37 percent, which is 1.73 percent higher than the year 2011. This growth of forest cover in the state, apart from afforestation in Indira Gandhi Canal Command Area, may be attributed to several plantation scheme launched during last ten years. Harit Rajasthan which was launched by the then Chief Minister Ashok Gehlot, which aimed to plant 25 lakh trees in the state over 61000 hectares of the forest land, but it remained just a number on paper. Apart from this Rajasthan planned to expand forest cover upto 20 percent of its total geographical area, as it has been envisaged by the Nation Forest Policy, but the desert state of Rajasthan achieved 4.85 percent forest cover till 2019. It is very less as compared to the target set, and it may be due to the climatic and geographic condition of the state, as more than two third of its area comes under Thar desert. The 15th forest cover assessment by FSI reveals that, whatever, the increase in forest cover has been observed, it is only due to the scrub cover, which normally grows by itself. There is an increase of total 466 sq.km. in the year 2017 as compared to 2015.

Therefore, we can say that whatever, the gain has occurred in 2019 may be attributed to afforestation in the Indira Gandhi Canal Command Area, due to fast growing species and conservation efforts.

Jaisalmer with a growth of 95.20 percent forest cover, recorded the highest growth, which is followed by Barmer with a forest covergrowth of 68.60 percent. If we categorize forest cover of Rajasthan into low, moderate, high and very high, we find that there are three districts, namely, Jhalawar (9.82), Jhunjhunun (3.07) and Pali (1.96), recorded low growth (below 10 percent) of forest cover during this period, whereas, three districts namely, Ajmer (10.10), Jodhpur (16.12) and Dungarpur (19.84) recorded moderate growth of forest cover (10.01 – 20 percent). Apart from these six districts, there are five districts, namely Bikaner (23.07), Bundi (22.95), Jalore (28.84), Nagaur (23.52) and

Rajsamand (23.11), recorded High growth of forest cover (20.01 – 30 percent), whereas, there are only two districts, namely, Barmer (68.60) and Jaisalmer (95.20) recorded very high growth of forest cover (above 30 percent). There are two districts, namely Dhaulpur and Sikar, which recorded no growth of forest cover during this period. But one of the surprising thing is that the overall growth of forest cover in the state of Rajasthan was 3.37 percent which is 1.73 percent higher than the year 2011, but, out of thirty three districts, there are fourteen districts, namely, Alwar, Banswara, Baran, Bharatpur, Bhilwara, Chittaurgarh, Churu, Ganganagar, Jaipur, Kota, Sawai Madhopur, Sirohi, Tonk and Udaipur recorded negative growth of forest cover during this period.

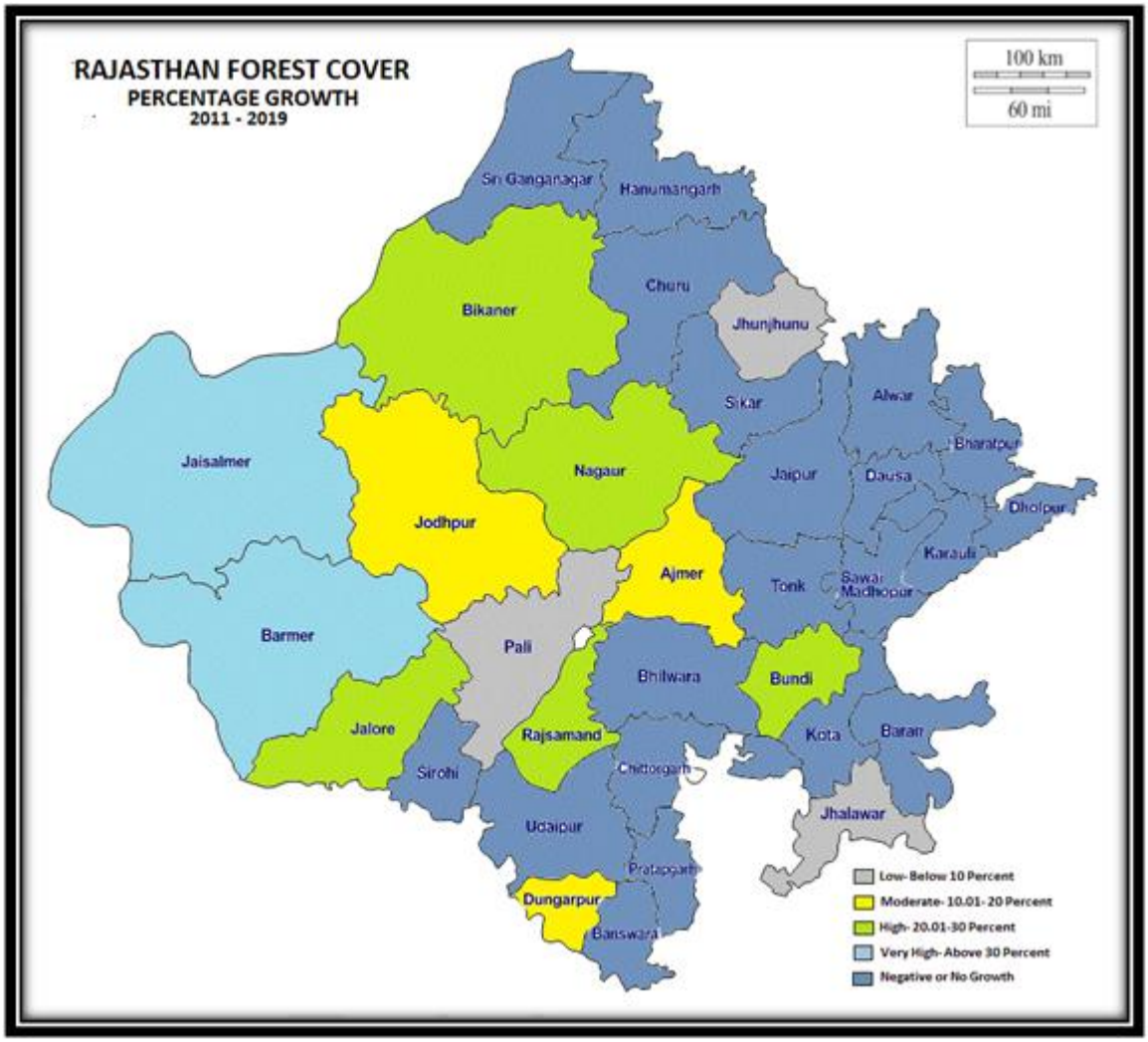

Figure 4

Therefore, it clearly reflects that there is little to cheer about the overall growth of forest cover in Rajasthan because, most the districts recorded negative growth rate. It is only became of the fact that various government plantation scheme, like Harit Rajasthan, which aimed to plant twenty five lakh trees over 61,000 hectares of forest land in the state was simply a number on papers. In the same way it happened with 1.3 crore samplings distributed to the common people of Rajasthan. Therefore we can say that whatever the growth of forest cover occurred during this period may be attributed to afforestation programs in Indira Gandhi canal command area as well as the scrubs which has grown by itself.

The natural growth of trees in forest is much slower than the rate at which forests are being cut down for different kind of products, therefore, afforestation helps to alleviate the pressure on natural forests. Afforestation provides both direct and indirect benefit in the study area apart from increase in the forest cover, especially in the districts of western Rajasthan, through which Indira Gandhi canal flows. In spite of the adverse conditions in western Rajasthan, Indira Gandhi Canal Project, under various programs, afforestation works were undertaken only because of the availability of the Himalayan water, and it remained successful. Most of the lands which were barren, some 15-20 years ago, now converted into thickly forested tract. As a result of the afforestation, the desert area in the districts of western Rajasthan has been transformed into long green belts as well as there has been a marked change in the micro-climate of the area. This afforestation also helps in protecting canal system and agricultural fields from the wind-borne sand depositions and shifting sand dunes. Apart from these Indira Gandhi canal proved to be a boon for the local inhabitants because it helped in providing water for drinking purpose and made available woods for local needs

as well as it provided irrigation facilities, which helped in enhanced productivity of crops.

In Rajasthan and especially, western Rajasthan through which Indira Gandhi canal flows, the price of fuel wood were sky rocketing. There were acute shortage of fuel wood in Indira Gandhi Nahar Project Canal Commaned Area. Afforestation became source of timber, fuel woods and charcoal to the inhabitants. *Prosopis julifera* use to meet the demand of fuel wood, because there is a growing tendency among people to cut the dried trees and convert them into fuel wood and charcoal. In the same way Phog trees also provided fire wood. Extensive Silvi pastoral plantation along the canal developed irrigated pastures, which enhanced the grass and fodder production. Afforestation has encouraged people to collect fodder for their cattles. There are several trees like Khejri, subabool, Babool, Kumta and Sainjana etc., which are being used as a fodder for animals.

Afforestation also helped in fighting against greenhouse effect, through photosynthesis, which contributed in the micro-climatic change. The dust storm which affects adjoining state has also been reduced upto some extent due to afforestation. During summer season dust storm causes large scale soil erosion, which has been reduced by planting trees like ziziphus nummularia, Panicum turgidum, Acacia tortilis, Acacia Senegal and Tamarix articulata etc. and sand dunes stabilization were made. The wind strength has been declined as well as number of dust storm has been reduced. Apart from this India has committed to create additional carbon sink of 2.5 to 3 billion tonnes by 2030, can also be met by massive afforestation in the canal command area. The direct link between greening and rainfall has not been yet proven in the semi-arid and arid region of Western Rajasthan. But recent study from China (Jin & Wang 2018) suggested that monsoon rains have increased in the Indo-Pak deserts by 30% over the last two decades, which has elevated the soil moisture content. This increase in soil moisture content has ultimately resulted into higher plants and crop growth, which led tobecome desert more greener. Increase in rainfall combined with irrigation facilities by means of Indira Gandhi Canal engaged more and more local communities in agriculture, which is somehow superior to cultural pastoralism. Agricultural land use has now changed from 1957-58 to 2014-15, in western Rajasthan. The net sown area has increased by 18.25 percent, double crop area by 14.75 percent and forest area by 1.61 percent. It has been observed that the culturable wasteland, current fallow land and old fallow land has been decreased. There is a growing desire among communities to grow crops; which are economically beneficial, which led to intensive agriculture from subsistence. There is no doubt that IGNP has transformed the agricultural condition, which has brought economic prosperity by means of distribution of canal water. Apart from this, improved variety of crops, development of agroforestry, horticulture and silvipastoral, helped farmer to lead better life. Afforestation programs in Indira Gandhi Canal Command Area will help people living over there, to manage different resources and combat desertification in the arid region of western Rajasthan.

2. Conclusion

Beside the project, the arid area was passing through the state of overgrazing and over exploitation, and vegetation were gradually reducing. Therefore, the ecological balance of the region was disturbed, leading to progressive degradation of its resources. The project has created most dense forest in Rajasthan in this arid region. Afforestation of shifting dunes not only eliminated the hazards they posed, but brought about durable benefits through improvement of soil fertility. The deposition of windblown sand in the canals has bee reduced considerably, thereby permitting water flow in canals almost round the year. Afforestation in the project area, apart from reducing the hazards of wind erosion and shifting dunes, has improved the microclimate, soil fertility and the yields of various crops. The forests are harboring large number wild life and are acting as a very good corridors for birds and other animals.

Degradation of agricultural land has been minimized because of the sand dunes, stabilization. The sandy hummocks and low dunes have been leveled and reclaimed to grow cereals, cotton and groundnuts. Agricultural productivity has been increased due to change in micro-climatic conditions, which led to increase in soil moisture content. Along with change in micro-climatic characteristics and irrigation facilities, have led to manifold increase in agricultural productivity as well as rearing of animals and farming of commercial crops. Afforestation along the canal roads and newly settled area has led to increase in fodder for animals as well as fuel woods have become available to the inhabitants living in the canal command area. Afforestation also helped in checking desertification of the fertile areas and ground water table rose at the rate 0.8 m/year, which led to elimination of drought conditions. Apart from improvement in vegetal cover, there has been a rapid rise in the number of villages and new colonies in the canal command area. There has been a percentage change in the attitude and life style of the people, which has resulted into urge for education and greater mobility.

The growth of forest cover from 1999 to 2019, clearly shows that the larger forest cover has been observed in those districts which are located in the western part of Rajasthan, through which Indira Gandhi Canal flows. The forest cover in the state is 16630 sq.km. which is 4.85 per cent of the total geographical areas in the year 2019, and this increase in forest cover may be attributed to the afforestation programs in Indira Gandhi Canal Command Area.

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