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SPATIO-TEMPORAL DIFFUSION OF NURSING INSTITUTES IN PUNJAB, INDIA

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Abstract

Nursing today demands a high level of knowledge and skill. The basic nursing education programmes strive to provide learning experiences that will equip the students to perform at a professional level. Nursing in India has its roots in Ayurvedic system dating back to around 3000 B.C. During the post-independence period, significant measures were taken to improve nursing education in India (Sakurikar, 2011). The years of liberalisation and globalization, more particularly the last decade of the 20th century, when demand for nurses from foreign lands was very large and acute, witnessed a dramatic proliferation of nursing institutes in India. Nurses' shortage in developed countries created a huge demand for nurse education which acted as a 'ticket' for going to foreign destinations for Punjabis. This resulted in a rapid increase in the number of nursing institutes in the State. It is in this context that the present paper, using secondary data, attempts to examine the trends in growth, patterns of distribution, ownership status and spatial distribution of nursing education institutes in the State. The study provides an insight on how after the introduction of new economic policy, with increased private investment, due to demand of nursing profession in the international market, the State witnessed a significant increase in the number of nursing institutes in the State with a major spread in rural areas.

Keywords: Nursing Education; Nursing Institutes; Punjab; Emigration and Foreign Destinations

Introduction

Punjab, being one of the developed states of the country, has a very well-developed network of educational institutions. After the reorganisation of Punjab in 1966 on a linguistic basis, the State government made tremendous efforts to improve and expand such institutes. The efforts made by the government resulted in the establishment of several new professional institutes in the State which were limited in number in the 1970s and 1980s (Ghuman et al., 2006). After that, there was an increase in demand for professional courses including nursing at national and international levels. Due to the increasing demand for professional courses, the central government was left with no choice but to allow entry of private sector in professional education (UGC Report, 2003). In this context, the study of nursing education institutes in Punjab assumes special significance as

the State has been experiencing tremendous growth of such institutes in order to provide adequate opportunities to its people to explore relevant future prospects in this field.

Study Area

Punjab, came into existence in 1966 and is situated in north-western India. Geographically, it lies from 29˚30' N to 32˚32' N latitude and 73˚55' E to 76˚50' E longitude. Punjab has twenty-two districts and seventy-seven tehsils. The total population of the State was 27,743,338 (Census 2011) out of which 52.8 per cent were males and 47.2 per cent females. Among the few Indian states that have a long history of migration, Punjab occupies a significant position. During pre-1947, migration from Punjab was comparatively small. It was during the post-1947 period especially from the 1960s onwards that Punjabis migrated in large number. The partition of Punjab led not only to a complex process of internal migration but also to overseas migration. The 64th round of National Sample Survey data (2007-2008) discloses that Punjab figures among those states (Kerala, Tamil Nadu, Andhra Pradesh, Gujarat and Goa) which registered the most emigrants from India. According to this survey, the number of emigrants from Punjab was estimated at 386,423 in the year 2007-2008. More recently, among various profession-oriented migration streams; the nursing profession is gaining tremendous importance in Punjab.

Database and Methodology

The present study is based largely on secondary sources of data collected from Indian Nursing Council; Punjab Nurses Registration Council; Gazetteer Reports; Five Year Plans Documents; relevant websites; and various books and journals. For mapping purposes, ArcGIS 10.3 has been used. Extensive field visits were also made by the first author to examine interactions between the existence of nursing institutes and people's perception of their growth in real life.

Results and Discussion

To achieve the objectives of the study, as mentioned above, this section is divided into four subheads to examine: (i) the trends in the growth of nursing institutes; (ii) pattern of distribution of nursing institutes; (iii) share of nursing institutes in government and private (aided and unaided) sectors; and (iv) salient features of spatiotemporal diffusion of nursing institutes in the State.

Nursing Institutes in Punjab: Trends in Growth

An assessment of data on the number of nursing institutes in the country revealed that in 2016, there were 1986 nursing institutes offering ANM diploma; 3123 offerings GNM diploma and 780 nursing institutes offering Post Basic B.Sc Nursing degree (Table 1). The number of B.Sc nursing institutes has increased to 1831 and there were 637 nursing institutes in the country offering M.Sc nursing degree in 2016 (Indian Nursing Council, 2016). This large number of nursing institutes in the country has been directly linked with the heavy demand of nurses in the health care sector both at national and international levels.

Around 59 per cent of nursing institutes were nurturing ANMs and GNMs; 29 per cent were providing B.Sc nursing degree while the remaining 21 per cent were offering Post Basic B.Sc Nursing and Postgraduate nursing in India (Indian Nursing Council, 2016). The lower percentage of higher education institutes in the country is probably due to lesser demand for higher education in the profession (FICCI, 2016). As far as the distribution of nursing institutes in 2016 in the country is concerned, such nursing institutes showed greater regional imbalances. There were states with a small size of the population and a large number of nursing institutes. On the other hand, there were some states which had a large size of the population and a small number of nursing institutes (Table 1). Karnataka, Madhya Pradesh, Maharashtra, Punjab, Tamil Naidu, Kerala, for example, had a higher concentration of nursing institutes while highly populated states such as Bihar, Jharkhand, West Bengal, Uttaranchal, Himachal Pradesh and Jammu Kashmir had a lower concentration of nursing institutes.

Punjab ranked third in terms of the total number of nursing institutes offering ANM diploma in the country in 2016. Out of the total, 9.01 per cent of ANM nursing institutes were located in Punjab. However, the top two positions were occupied by Maharashtra (28.39 per cent) and Uttar Pradesh (10.12 per cent). In the context of GNM diploma offering nursing institutes, Punjab with 6.94 per cent out of the total institutes, occupied the fifth position in India in 2016. The leading states in terms of the number of GNM nursing institutes included Karnataka (16.45 per cent), Madhya Pradesh (11.59 per cent), Maharashtra (8.54 per cent) and Uttar Pradesh (8.10 per cent). Among Post Basic B.Sc nursing institutes, Punjab with 12.48 per cent occupied the second rank after Karnataka (24.74 per cent). Punjab ranked seventh in term of the number of institutes offering B.Sc Nursing degree with a total of 5.67 per cent of B.Sc. degree nursing institutes of the country in 2016. The State stood at fifth position in terms of the total number of nursing institutes offering M.Sc degree with 6.43 per cent of nursing institutes of the country offering M.Sc. nursing degree in 2016.

Punjab being sixteenth largest State by population has the lowest burden of population per institute (excluding union territories) (Table 1). This indicated the proliferation of a large number of nursing institutes in the State due to the heavy demand of the nursing profession in foreign destinations and a craze to emigrate among the people of Punjab. Thus, Punjab is a forthcoming State in term of its capacity to train nurses given the position of the leading State in terms of the number of nursing education institutes in the country. There were total 253 nursing institutes in the State in 2016 offering various courses including ANM, GNM, B.Sc Nursing, Post Basic B.Sc nursing and M.Sc. nursing (Table 2 and Figure 1). Such a large number of nursing institutes in the State is a result of the huge demand for trained nurses and nursing personnel at national and international levels. The recent number of nursing institutes in the State shows that Punjab is emerging as one of the leading states to supply nurses although, Kerala has had a long tradition of training nurses for international migration. Punjab with deep roots of a traditionally established strong culture of international migration has always been looking for opportunities abroad. Migration to foreign destinations has become a status symbol among Punjabis.

Table 1. Distribution of Nursing Programmes Offered by Nursing Institutes (2016) and Population served (2011) in India

State/Union Territory	ANM	GNM	P.B. B.Sc (N)	B.Sc (N)	M.Sc (N)	Total Population	Population per Institute Programmes*
Andaman and Nicobar	1	0	0	1	0	3,80,581	1,90,290.50
Andhra Pradesh	46	164	30	146	32	4,93,78,776	1,18,131.04
Arunachal Pradesh	6	7	0	1	0	13,83,727	98,837.64
Assam	27	35	4	11	5	3,12,05,576	3,80,555.80
Bihar	102	19	1	5	0	10,40,99,452	8,19,680.72
Chandigarh	1	0	1	2	1	10,55,450	2,11,090.00
Chhattisgarh	88	78	18	87	16	2,55,45,198	89,007.66
Dadra and Nagar Haveli	0	0	1	1	1	3,43,709	1,14,569.67
Delhi	9	18	3	11	6	1,67,87,941	3,57,190.23
Goa	2	1	1	3	1	14,58,545	1,82,318.13
Gujarat	111	117	18	69	13	604,39,692	1,84,267.35
Haryana	90	82	27	35	8	2,53,51,462	1,04,758.11
Himachal Pradesh	7	38	5	21	2	68,64,602	94,035.64
Jammu and Kashmir	14	16	4	12	2	1,25,41,302	2,61,277.13
Jharkhand	63	28	5	9	1	3,29,88,134	3,11,208.81
Karnataka	34	514	193	329	178	6,10,95,297	48,954.56
Kerala	20	204	51	133	67	3,34,06,061	70,328.55
Madhya Pradesh	101	362	62	158	45	7,26,26,809	99,762.10
Maharashtra	564	267	57	100	36	11,23,74,333	1,09,740.56
Manipur	8	15	0	7	0	28,55,794	95,193.13
Meghalaya	2	7	1	2	1	29,66,889	2,28,222.23
Mizoram	3	5	0	2	0	10,97,206	1,09,720.60
Nagaland	2	5	1	1	0	19,78,502	2,19,833.56
Orissa	133	78	6	20	9	4,19,74,218	1,70,626.90
Pondicherry	7	8	7	15	7	12,47,953	28,362.57
Punjab	**179 (9.01)**	**217 (6.94)**	**92 (11.79)**	**104 (5.67)**	**41 (6.43)**	**2,77,43,338**	**43,828.34**
Rajasthan	29	179	47	168	24	6,85,48,437	1,53,352.21
Sikkim	1	2	1	2	1	6,10,577	87,225.29
Tamil Nadu	43	215	77	176	82	7,21,47,030	1,21,664.47
Telangana	18	91	18	85	25	3,50,80,690	1,48,019.79
Tripura	3	5	1	4	2	36,73,917	2,44,927.80
Uttar Pradesh	201	253	31	71	14	19,98,12,341	3,50,547.97
Uttaranchal	22	25	6	18	5	1,00,86,292	1,32,714.37
West Bengal	49	68	11	22	12	9,12,76,115	5,63,432.81
India	**1,986**	**3,123**	**780**	**1,831**	**637**	**1,21,08,54,977**	**1,44,891.11**

Sources: *Indian Nursing Council, 2016; Census of India, 2011*

Note: *(i) * As the data pertaining to total number of nursing institutes in Indian states is not available it is calculated as the population size of the State divided by total number of nursing programmes offered by the State. (i) ANM: Auxiliary Nursing and Midwifery; GNM: General Nursing and Midwifery; PB.B.Sc (N): Post-Basic Bachelor of Science in Nursing; B.Sc (N): Bachelor of Science in Nursing; and M.Sc (N): Masters of Science in Nursing (ii) Figures in parentheses are percentages calculated with the help of total data pertaining to India*

Out of a total of 25 million international migrants from India, around 8 per cent or estimated two million were Indian Sikhs, dispersed over 75 countries, in South East Asia, East Asia, Australia, Africa, Europe and North America (Thandi, 2017). International migration has taken place from all the districts of the State through the Doaba region remained Non-Resident Indians heartland for a long time (Kaur, 2006). The demand for nurses in foreign lands has also attracted the attention of Punjabis. Nursing profession in the State is providing good opportunities to the Punjabis to get visas on their passports.

Table 2. Punjab: Total Number of Nursing Institutes (Course-Wise), 2016

Sl.No.	Courses Offered	Number of Institutes offering the Course
1	ANM Diploma	24
2	GNM Diploma	38
3	B.Sc Nursing	4
4	ANM and GNM Diploma	76
5	ANM and B.Sc Nursing	2
6	GNM and B.Sc Nursing	5
7	B.Sc Nursing and Post Basic B.Sc Nursing	5
8	GNM and Post Basic B.Sc Nursing	3
9	ANM, GNM and B.Sc Nursing	9
10	ANM, GNM and Post Basic B.Sc Nursing	8
11	GNM, B.Sc Nursing and Post Basic B.Sc Nursing	7
12	GNM, B.Sc Nursing and M.Sc Nursing	2
13	B.Sc Nursing, Post Basic B.Sc Nursing and M.Sc Nursing	1
14	ANM, GNM, B.Sc Nursing and Post Basic B.Sc Nursing	31
15	GNM, B.Sc Nursing, Post Basic B.Sc Nursing and M.Sc Nursing	9
16	ANM, GNM, B.Sc Nursing and M.Sc Nursing	1
17	ANM, GNM, B.Sc Nursing, Post Basic B.Sc Nursing and M.Sc Nursing	28
Total Number of Nursing Institutes		**253**

Source: *Indian Nursing Council, 2004-2016; All India Survey of Higher Education, 2016; Primary data collected by the researcher, 2016*

Note: *(i) ANM: Auxiliary Nursing and Midwifery; GNM: General Nursing and Midwifery; PB.B.Sc (N): Post-Basic Bachelor of Science in Nursing; B.Sc (N): Bachelor of Science in Nursing; and M.Sc (N): Masters of Science in Nursing*

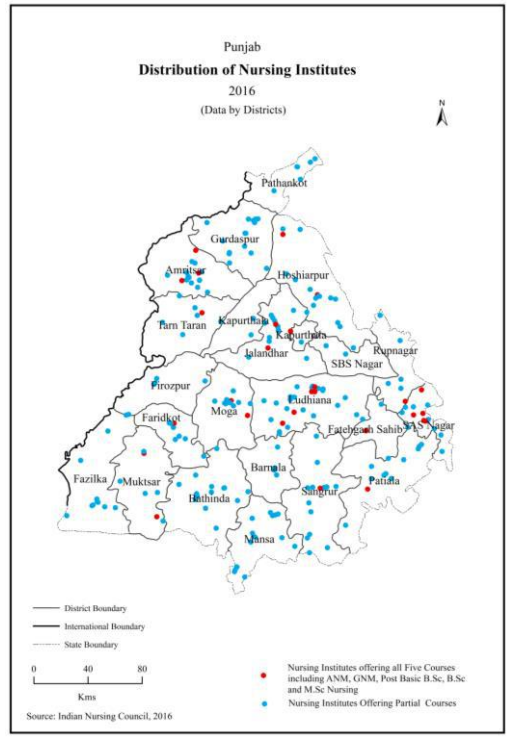

Fig. 1. Distribution of Nursing Institutes in Punbaj - 2016

Social networks abroad including family members and friends; immigration consultants and agents are guiding Punjabis to choose the nursing profession as a career for permanent settlement in the foreign land. This huge demand for nurses abroad, subsequently, resulted in a rapid expansion of nursing institutes in the State (Figure 1). An assessment of data on number and growth of nursing institutes revealed that prior to the new economic policy, during the period 1966 to 1991, there was a small increase in the number of nursing institutes in the State. In 1966, when Punjab gained full statehood there were only 4 nursing institutes offering ANM diploma and 3 nursing institutes offering GNM diploma. For the next two decades i.e. in 1971-1981 and 1981-1991, there was a marginal increase in the number of nursing institutes offering ANM and GNM diploma in the State.

The undergraduate and postgraduate nursing courses started late in the State. The development of institutes offering Post Basic B.Sc Nursing programme in Punjab started late i.e. after 1991. Till 1991, this was the only one nursing institute in Punjab offering B.Sc nursing degree and M.Sc nursing degree to the aspirant. However, a noticeable percentage increase in nursing institutes has been observed after the New Economic Policy. During the period 1991 to 2016, the number of nursing institutes offering ANM diploma increased from 14 to 179; the number of nursing institutes offering GNM diploma increased from 12 to 217; the number of nursing institutes offering B.Sc nursing increased from 4 to 104; the number of nursing institutes offering M.Sc nursing increased from 1 to 41 in the State. The growth of nursing Institutes including M.Sc Nursing has though been rapid during the periods between 2006 and 2011; between 2011 and 2016 yet the number of such institutes was very low and continued to witness rapid but the lowest rate of growth among all institutes in the State as students with M.Sc nursing generally wish to adopt teaching and research as their career and not nursing as their profession (Figure 2).

The Post Basic B.Sc Nursing degree started late in the State in 2001 with only one college offering this degree, later on, with the rising demand, the number of Post Basic B.Sc nursing institutes increased to 92 in the State in 2016. The New Economic Policy of 1991 adopted by the government of India greatly influenced the professional education sector including nursing in the country. Moreover, the demand of the nursing profession due to continuing crisis of trained and qualified nurses in the developed countries of the world provided a new route to Punjabis to emigrate to foreign destinations through the nursing profession. This resulted in a rapid expansion of nursing institutes in the State.

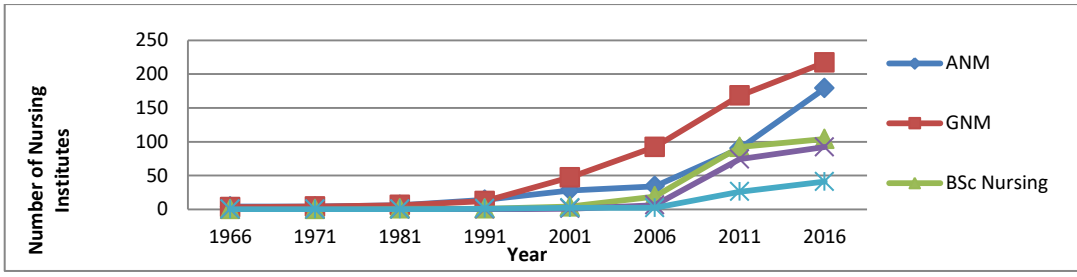

Fig. 2 Punjab: Growth of Nursing Institutes 1966-2016

***Sources**: Indian Nursing Council, 2004-2016; All India Survey of Higher Education, 2016; Primary data collected by researcher, 2016*

Nursing Institutes in Punjab: Pattern of Distribution

Before the introduction of the New Economic Policy of 1991 all the ANM diploma offering institutes were concentrated mostly in the urban areas of the State (Table 3). After 1991, the number of ANM diploma offering nursing institutes showed a rapid increase in rural areas as well. The number of such institutes in rural areas increased from 2 in 1991 to 117 in 2016. In urban areas, such as nursing institutes, however, increased from 4 in 1966 to 62 in 2016. It is noticeable that the percentage share of ANM diploma offering nursing institutes in rural areas increased from 14.3 per cent in 1991 to 65.4 per cent in 2016 while for urban areas the percentage share of such nursing institutes decreased from 85.7 per cent in 1991 to 34.6 per cent in 2016 (Table 3). The percentage share of ANM diploma offering nursing institutes in rural areas was high because about 62.5 per cent of the population in Punjab was living in rural areas and only 37.4 per cent was residing in urban areas in 2011 (Census of India, 2011); rural inhabitants were also interested in acquiring nursing education because of its heavy demand in foreign lands. Moreover, during the primary survey, it was discovered that demand of nursing education is higher in rural Punjab as compared to urban areas of Punjab as more emigration has been taking place from rural areas than from urban areas of the State.

Distribution of GNM diploma offering nursing institutes in rural and urban areas of Punjab shows almost similar pattern as in the case of ANM nursing institutes. Prior to the introduction of globalisation and liberalisation, till 1981, all the GNM diploma offering nursing institutes were concentrated only in urban areas of the State. In 1991 only 16.7 per cent (two in number) of the total GNM nursing institutes were located in rural areas and the remaining 83.3 per cent of GNM nursing institutes were located in urban areas. After 1991, Policy of Liberalisation led to the commendable quantitative expansion of nursing institutes in rural Punjab. The percentage share of GNM nursing institutes in rural areas thus rose to 31.9 per cent in 2001 and 46.7 per cent in 2006 (Table 3). The entry of private sector in nursing education resulted in the expansion of more than 50 per cent of GNM nursing institutes in rural Punjab in 2011 and 2016 (Table 3). The Policy of Liberalisation thus promoted the expansion of GNM nursing institutes particularly in the private sector in rural Punjab.

Consequently, the percentage share of GNM nursing institutes in urban areas has constantly been declining from 68.1 per cent in 2001 to 44.1 in 2011 and 42.4 per cent in 2016 (Table 3). Availability of land at lower prices in rural areas and well-developed road network in the State allured private entrepreneurs to invest in nursing institutes in these areas of the State. As far as distribution of Post Basic B.Sc nursing institutes in rural and urban areas was concerned, a similar pattern was observed as was in case of nursing institutes offering ANM diploma and GNM diploma. It was observed that the majority of Post Basic B.Sc nursing institutes was located in rural areas accommodating a large majority of the state's population. In 2011 about 59.5 per cent of Post Basic B.Sc nursing institutes were located in rural areas as compared to 40.5 per cent in urban areas (Table 3). Further in 2016, on the one hand, the per cent share of rural Post Basic B.Sc nursing institutes

increased to 66.3 per cent while, on the other hand, per cent share of urban colleges decreased to 33.7 per cent.

This change in rural and urban percentage was due to the establishment of the majority of colleges in rural areas under private management. Also, 81 per cent of people emigrating from Punjab belonged to rural Punjab (Patel, 2015). The demand for nursing degree holders in foreign countries attracted investors to establish nursing institutes in rural Punjab. Until 1991 there was only one nursing institute in the State which offered B.Sc nursing degree and it was located in Ludhiana city. After the Policy of Liberalisation, Globalisation and Privatization the per cent share of B.Sc nursing institutes located in rural areas showed an increasing trend. In 2001, out of a total of four institutes, 3 B.Sc nursing institutes were located in urban areas and one institute was in the rural area. In 2006, the per cent share of BSc nursing institutes remained high in urban areas as compared to rural areas. However, in 2011, 64.1 per cent of B.Sc nursing institutes were located in rural areas as against 35.9 per cent located in urban areas. In 2016, the per cent share of B.Sc nursing institutes in urban areas increased to 37.5 per cent and in rural areas, it slightly declined (Table 3). As far as the growth of postgraduate nursing institutes is concerned, in the initial stage, such institutes were only in urban areas. Till 2006 there were only two Post Graduate nursing institutes in the State and both of them were located in urban areas.

Table 3. Punjab: Rural-Urban Distribution of Nursing Institutes offering Different Programmes, 1966-2016

Year	1966		1971		1981		1991		2001		2006		2011		2016	
Program	R	U	R	U	R	U	R	U	R	U	R	U	R	U	R	U
ANM	0	4 (100)	0	4 (100)	0	7 (100)	2 (14.3)	12 (85.7)	7 (25)	21 (75)	10 (29.4)	24 (70.6)	56 (62.2)	34 (37.8)	117 (65.4)	62 (34.6)
GNM	0	3 (100)	0	4 (100)	0	6 (100)	2 (16.7)	10 (83.3)	15 (31.9)	32 (68.1)	43 (46.7)	49 (53.3)	94 (55.9)	74 (44.1)	125 (57.6)	92 (42.4)
P.B. B.Sc (N)	0	0	0	0	0	0	0	0	0	1 (100)	1 (16.7)	5 (83.3)	44 (59.5)	30 (40.5)	61 (66.3)	31 (33.7)
B.Sc (N)	0	0	0	0	0	1 (100)	0	1 (100)	1 (25)	3 (75)	8 (42.1)	11 (57.9)	59 (64.1)	33 (35.9)	65 (62.5)	39 (37.5)
M.Sc (N)	0	0	0	0	0	0	0	1 (100)	0	2 (100)	0	2 (100)	13 (50.00)	13 (50.00)	20 (48.8)	21 (51.2)

Sources: *Indian Nursing Council, 2004-2016; All India Survey of Higher Education, 2016; Primary data collected by researcher, 2016*

Note: *(i) R: Rural Area; U: Urban Area (ii) ANM: Auxiliary Nursing and Midwifery; GNM: General Nursing and Midwifery; PB.B.Sc (N): Post-Basic Bachelor of Science in Nursing; B.Sc (N): Bachelor of Science in Nursing; and M.Sc (N): Masters of Science in Nursing (iii)Figures in parentheses show percentage share of number of nursing institutes offering different programmes in rural/urban*

By 2011, there was an equal number of M.Sc nursing institutes i. e. 13 each in both rural and urban areas in the State (Table 3). In 2016, 51.2 per cent of the total postgraduate nursing institutes in the State were located in urban areas as against 48.8 per cent in rural areas. (Table 3). Until 1991 there was only one nursing institute in the State which offered B.Sc nursing degree and it was located in Ludhiana city. After the Policy of Liberalisation, Globalisation and Privatization the per cent share of B.Sc nursing institutes located in rural areas showed an increasing trend. In 2001, out of a total of four institutes, 3 B.Sc nursing institutes were located in urban areas and one institute was in the rural area. In 2006, the per cent share of BSc nursing institutes remained high in urban areas as compared to rural areas.

However, in 2011, 64.1 per cent of B.Sc nursing institutes were located in rural areas as against 35.9 per cent located in urban areas. In 2016, the per cent share of B.Sc nursing institutes in urban areas increased to 37.5 per cent and in rural areas, it slightly declined (Table 3). As far as the growth of postgraduate nursing institutes is concerned, in the initial stage, such institutes were only in urban areas. Till 2006 there were only two Post Graduate nursing institutes in the State and both of them were located in urban areas. By 2011, there was an equal number of M.Sc nursing institutes i. e. 13 each in both rural and urban areas in the State (Table 3). In 2016, 51.2 per cent of the total postgraduate nursing institutes in the State were located in urban areas as against 48.8 per cent in rural areas. (Table 3).

Nursing Institutes in Punjab: Share of Government and Private (Aided and Unaided) Sectors

In 1966 the percentage share of government-owned ANM diploma offering nursing institutes was 50 per cent and it rose to 71.4 per cent in 1981 (Table 4). This share decreased to 3.9 per cent in 2016. This sharp decline in the share of government-owned ANM diploma nursing institutes was due to liberalisation granted to private agencies to open education institutes in 1991. Though the number of government-owned ANM nursing institutes remained stagnant at 7 during 1991-2016 yet their percentage share declined continuously as the share of private unaided ANM nursing institutes increased consistently during this period (Table 4). The private (both aided and unaided) ANM nursing institutes, however, displayed large variations in terms of their share in the total ANM nursing institutes (including government and private) in the State during the same period (Table 4).

As far as the distribution of GNM diploma offering nursing institutes in the State on the basis of ownership status is concerned, it may be noted that in 1966 and 1971 there were only 3 and 4 GNM diploma offering nursing institutes respectively in the State and all of them were private-aided in ownership status. The percentage share of government-owned GNM offering institutes was highest (33.3 per cent) in 1981 in the State. After 1981 the percentage share of government-owned GNM diploma offering nursing institutes started declining and decreased to 3.6 per cent in 2011 (Table 4). Between 2011 and 2016, the State government opened 5 new GNM training institutes which resulted in a slight increase in the share of government-owned GNM diploma nursing institutes in the State in 2016 (Table 4). The percentage share of private aided GNM diploma nursing institutes also showed a declining trend after 1981(Table 4). The entry of the private sector in establishing nursing institutes in the State, after 1991 resulted in a noticeable expansion of GNM diploma nursing institutes in the private sector. The percentage share of private unaided GNM diploma nursing institutes rose from 41.7 per cent in 1991 to 67.2 per cent in 2016. Privatisation thus played an important role in enhancing the number of GNM nursing institutes, particularly in the private unaided sector.An analysis of data of the distribution of Post Basic B.Sc nursing institutes by ownership revealed that after 2001 a significant number of nursing institutes was opened under private management as compared with government-owned institutes.

In 2001 there was only one private aided nursing institute in the State offering Post Basic B.Sc Nursing degree and this number rose to 3 in 2006. The share of private aided Post Basic B.Sc nursing institutes decreased from 29.8 per cent in 2011 to 27.2 per cent in 2016. The share of private unaided Post B.Sc nursing institute which was 67.5 per cent in 2011 however further rose to 69.6 per cent in 2016 (Table 4). It may be noted that only 2 institutes were under government management in 2011 which accounted for only 2.7 per cent of the total number of such institutes. This percentage rose to 3.2 per cent in 2016 with an addition of one institute under government management. Such an arrangement showed a monopoly of the private sector, in terms of the ownership status of Post Basic B.Sc Nursing Institutes in the State. The number of private aided nursing institutes offering B.Sc nursing degree increased to 28 in 2016 from 1 in 1981. In 2011, there were 62 nursing institutes offering B.Sc nursing degree in the private unaided sector. These accounted for 67.3 per cent of total such institutes owned by the State. The number of such institutes rose to 70 in 2016 (Table 4). Till 1991 there was only one college offering B.Sc nursing degree in private aided management in the State.

Table 4. Punjab: Number of Nursing Institutes offering Different Programmes in Government, Private Aided and Unaided Sectors, 1966-2016

Year	1966			1971			1981			1991			2001			2006			2011			2016		
Location	G	PA	PU	G	PA	PU	G	PA	PU	G	PA	PU	G	PA	PU	G	PA	PU	G	PA	PU	G	PA	PU
ANM	2 (50)	2 (50)	0	2 (50)	2 (50)	0	5 (71.4)	2 (28.6)	0	7 (50)	3 (21.4)	4 (28.6)	7 (25)	6 (21.4)	15 (53.6)	7 (20.6)	7 (20.6)	20 (58.8)	7 (7.8)	27 (30)	56 (62.2)	7 (3.9)	55 (30.8)	117 (65.3)
GNM	0	3 (100)	0	0	4 (100)	0	2 (33.3)	4 (66.7)	0	2 (16.6)	5 (41.7)	5 (41.7)	4 (8.5)	15 (31.9)	28 (59.6)	4 (4.3)	28 (30.5)	60 (65.2)	6 (3.6)	52 (30.9)	110 (65.5)	11 (5.1)	60 (27.7)	146 (67.2)
P.B. B.Sc (N)	0	0	0	0	0	0	0	0	0	0	0	0	0	1 (100)	0	2 (33.3)	3 (50)	1 (16.7)	2 (2.7)	22 (29.8)	50 (67.5)	3 (3.2)	25 (27.2)	64 (69.6)
B.Sc (N)	0	0	0	0	0	0	0	1 (100)	0	0	1 (100)	0	1 (25)	3 (75)	0	3 (15.8)	9 (47.4)	7 (36.8)	4 (4.4)	26 (28.3)	62 (67.3)	6 (5.8)	28 (26.9)	70 (67.3)
M.Sc (N)	0	0	0	0	0	0	0	0	0	0	1 (100)	0	0	1 (100)	1 (100)	0	1 (100)	1 (100)	1 (3.9)	5 (19.2)	20 (76.9)	2 (4.9)	5 (12.2)	34 (82.9)

Sources: *Indian Nursing Council, 2004-2016; All India Survey of Higher Education, 2016; Primary data collected by researcher, 2016*

Note: *(i) G: Government; PA: Private Aided; PU: Private-Unaided (ii)Figures in parentheses show percentage share of number of nursing institutes offering different programmes in rural/urban (iii) ANM: Auxiliary Nursing and Midwifery; GNM: General Nursing and Midwifery; PB.B.Sc (N): Post-Basic Bachelor of Science in Nursing; B.Sc (N): Bachelor of Science in Nursing; and M.Sc (N): Masters of Science in Nursing (iv) G: Government; PA: Private Aided; PU: Private-Unaided*

The number of private aided B.Sc nursing degree institutes rose to 3 in 2001; 9 in 2006; and finally 28 in 2016. In 2001, there was only one government-managed B.Sc nursing institute in the State. The number of such institutes rose to 4 in 2011and 6 in 2016 (Table 4). With regard to M.Sc nursing institutes, it was observed that the majority of postgraduate colleges was owned by the private sector in the State. There were only two government-owned nursing institutes offering a postgraduate degree in nursing in 2016 as against only one such institute in 2011in the State. The per cent share of private aided post-graduate nursing institutes also declined from 19.2 per cent in 2011 to 12.2 per cent in 2016 (Table 12).

However, the per cent share of private unaided post-graduate nursing institutes continued to rise from 76.9 per cent in 2011 to 82.9 per cent in 2016. This showed a wide gap in the number of privately owned and government-owned post-graduate nursing institutes in the State. The demand for nursing education was, thus, so strong in the State that private institutions with heavy investments were set up to be adequately accessed by students desirous of continuing nursing education in the State.

Spatio-Temporal Diffusion of Nursing Institutes in Punjab: Salient Features

Presently, nursing training is given in almost all the leading medical institutes in the State. The proliferation of nursing institutes in the State was the outcome of people's strong need and desire to acquire nursing education to support them strongly for emigrating to foreign lands. In total, there were 253 nursing institutes offering different nursing courses in 2016, in Punjab (Figure 1 and 2). These institutes were in both rural and urban areas and under different sectors of ownership. Some of the striking observations, in this context, are mentioned below:

1. In 2016, as many as 28 nursing institutes, out of a total of 253, were distributed in the districts of Amritsar, Faridkot, Fatehgarh Sahib, Hoshiarpur, Jalandhar, Ludhiana, Moga, Sahibzada Ajit Singh Nagar, Sri Muktsar Sahib, Patiala, Ropar, Sangrur and Tarn-Taran and offered all the five nursing courses including ANM, GNM, B.Sc Nursing, Post Basic B.Sc Nursing and M.Sc nursing in Punjab (Figure 1).
2. As per 2016 data, the largest number of nursing institutes (217) had offered GNM diploma course followed by ANM (179) diploma course (Table1). GNM diploma was the first nursing course to be introduced, in 1923, at Frances Newton Hospital, in Ferozepur district. Subsequently, the ANM course was introduced at Saint Mary's Hospital, Tarn-Taran in the year 1951.
3. GNM and ANM courses have traditionally been chosen by a large majority of students aspiring for the nursing profession. The introduction of degree courses including B.Sc Nursing, Post Basic B.Sc Nursing and M.Sc nursing is a recent development in the State in view of the high demand of this profession in foreign countries.
4. Majority of nursing institutes offering B.Sc nursing; Post Basic B.Sc Nursing and M.Sc nursing degrees in the State were established after the New Economic Policy of 1991 due to heavy demand of nursing degree in the global nurse market. M.Sc Nursing (not in great demand), however, was offered by only 41 institutes.
5. Ludhiana registered the highest number (30) of nursing institutes in the State in 2016. It was followed by Jalandhar (20); Bathinda (19); Gurdaspur (18); Hoshiarpur (17); Amritsar (17); Mansa (16); Sangrur (14); Sahibzada Ajit Singh Nagar (14); Patiala (12); Moga (11); Fazilka (10); Faridkot (9); Tarn-Taran (9); Ropar (7); Sri Muktsar Sahib (7); Ferozepur (6); Barnala (5); Pathankot (5); Fatehgarh Sahib (3); Kapurthala (3); and Shaheed Bhagat Singh Nagar (1) (Figures 1 & 2).
6. The districts of Bathinda, Jalandhar, Amritsar and Sahibzada Ajit Singh Nagar are emerging as new hubs for educational development in Punjab where people from far off places, especially of rural areas, are coming, particularly for nursing education (Field Survey, 2017).

7. Only seven districts viz. Ludhiana, Jalandhar, Bathinda, Gurdaspur, Hoshiarpur, Amritsar, and Mansa contributed to more than 50 per cent of the total nursing institutes in the State. The newly carved out districts of the State including Barnala, Fatehgarh Sahib, Kapurthala, Pathankot and Shaheed Bhagat Singh Nagar contributed to less than 7 per cent of the total nursing institutes.
8. There was a noticeable difference in the trend in the growth of nursing institutes located in rural and urban areas. The number of nursing institutes offering ANM diploma located in rural areas increased from 2 in 1991 to 117 in 2016. In urban areas, however, the number of such institutes increased from 12 in 1991 to 62 in 2016. A higher increase, in the number of nursing institutes in rural areas than in urban areas, was the result of the well-developed road network connecting remote rural areas with urban areas in the State; availability of land at a cheaper price in rural areas; more emigration taking place from rural areas; and a majority (62.52 per cent) of the population residing in rural areas.
9. The number of private unaided institutes increased from 4 in 1991 to 117 in 2016 and the private aided nursing institutes rose from 3 in 1991 to 55 in 2016. The number of government owned nursing institutes offering ANM diploma however remained stagnant during the same period. It may be noted that all government nursing institutes offering GNM; B.Sc nursing and M.Sc nursing witnessed a lower growth rate than private nursing institutes during this period. After the New Economic Policy of 1991, the private sector witnessed an impressive start about opening up of new nursing institutes and significant growth of private (both unaided and aided) nursing institutes was registered in the State particularly in the beginning of the present century.
10. Nursing Institutes offering higher education including Masters in Nursing are very few as compared with nursing institutes offering preliminary education in nursing. Such a pattern may be attributed to the fact that the institutes offering preliminary nursing education are needed just to support initial education required to emigrate to foreign lands; institutes offering higher education, on the other hand, are meant for strengthening teaching and research.
11. The above-mentioned nursing institutes offering ANM; GNM; Post Basic B.Sc nursing; were present in all the districts of the State. The nursing institutes offering M.Sc nursing were, however, present in a few districts only. Lack of career opportunities after obtaining higher education in nursing discouraged nursing students to continue higher education in this profession. The demand of nurses in developed nations due to nurses' shortage there, however, inspired Punjabis to choose this profession with preliminary nursing education serving as a safe mode to move to foreign destinations. This increased the number of nursing institutes in the State.
12. Ludhiana, most populous and most urbanized district, of the State (Census 2011) has the distinction of having the highest number (30) of nursing institutes in Punjab. Ludhiana district topped the list with the highest number (5) of nursing institutes offering all the five programmes including ANM, GNM, Post Basic B.Sc Nursing, B.Sc Nursing and M.Sc nursing degree in the State in 2016 (Figure 1). The Christian Medical College and Hospital, (CMCH) in Ludhiana is known as Asia's first medical school for women

(Kaur, 2019). The School of Nursing was started in CMCH in 1889 by converting an abandoned church into a hospital and in 1973 College of Nursing was established which offered four-year degree program in nursing. In 1987, the first-ever M.Sc nursing programme in the State was introduced by this college.

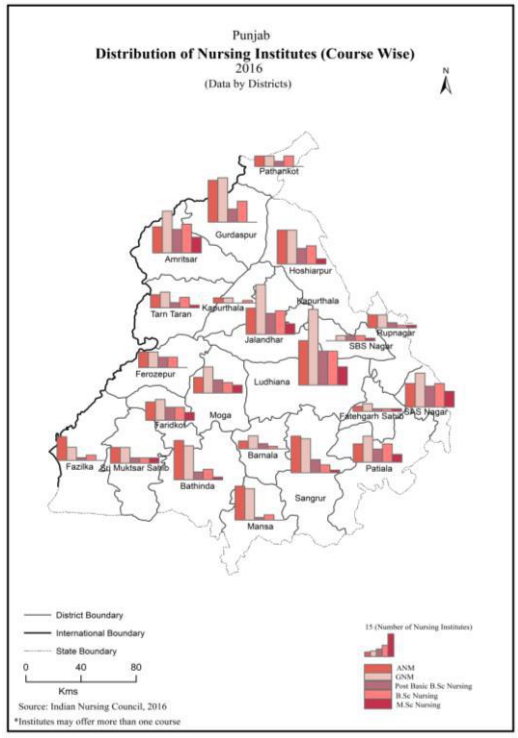

Fig. 3. Distribution of Nursing Institutes in Punbaj - 2016

Conclusion

As far as growth of nursing institutes in Punjab is concerned it may be noted that the period between 1966 and 1990, witnessed (i) a slow growth of such institutes; and (ii) their large concentration in urban areas. After 1991, increased private investment lead to the rapid growth of nursing institutes and resulted in their vast diffusion in rural areas of the State due to availability of rural land at cheaper rates and developed transport network in the State. The period between 2006 and 2011 witnessed the highest increase in the number of nursing institutes in the State. The spectacular growth of such institutes in the State was linked with booming opportunities for this profession abroad. A significant rise in the number of nursing institutes in the State of Punjab particularly during 2006-2011 was thus, due to the heavy demand of nurses both in the domestic and international markets. After 2011 the number of nursing institutes continued to rise but at a slower pace due to eased immigration policies adopted by favoured destinations, for emigration, including Canada and Australia. The opening up of other routes of emigration for Punjabis restricted the magnitude of emigration with the nursing profession. In 2016, nursing institutes were found in all the districts of the State.

Ludhiana, Jalandhar, Amritsar had a larger share (26.48 per cent) of nursing institutes while the districts of Fatehgarh Sahib, Barnala, Sri Muktsar Sahib and Shaheed Bhagat Singh Nagar accommodated only 6.3 per cent of such institutes in the State. Out of a total of 253 nursing institutes in the State, Master's Programme was offered by only 41 institutes; as this programme was selected by only those candidates who performed well at the graduation level and decided to opt for a career in higher education in nursing in native land instead of migrating to foreign lands for greener pastures. The basic programmes such as GNM, ANM, B.Sc. etc. required for emigrating were, however, introduced by all the nursing institutes in the State to cater to the huge demand of its people. The nature of nursing education and training provided by the large number of nursing institutes which grew in the State in such a short period of time, however, needs to be investigated further.

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IMPLICATIONS OF FOREST COVER CHANGE ON STREAM FLOW IN SENAPATI DISTRICT OF MANIPUR, INDIA

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Abstract

The forests today are more threatened than in the past. Human activities like clear-cutting or rotational felling of trees either for the Jhum site or fuel-wood makes major influences on the hydrological regime of a given area. The goal is to identify the impacts on seasonal streams flow at two selected streams of different source regions; controlled forest and degraded forest. The stream of the former remained with the flow throughout the year, where, in the latter, completely dried out during the dry months. The significance is that sustainable forest and water management can be taken as a priority for long run water availability.

Keywords: Threatened, Hydrological, Controlled, Degraded, Sustainable

Introduction

As human beings learned farming some 9000-10000 years ago in semi-arid regions of Anatolia, Mesopotamia, Iranian Plateau and Indus Valley and departed from their foraging culture to the emerging agriculture, the easiest way to clear the land of bushes and weeds was to set it 'on fire', since Bronze Age culture was still 4-5 millennia ahead and without metallic implements clearing deep forests were not easy. The 'fire' was the single most potent weapon against the unwieldy Nature and thus started the 'slash and burn' culture of agriculture ('shifting cultivation' or *Jhum*). However, in those early days, with the human groups being very small, there was hardly any noticeable imprint on the natural ecosystem. As human beings spread out colonising different areas around the globe and under different environmental conditions and as the population grew and technology changed to iron tools, the belief in protecting nature and conserving forests resources becomes no longer feasible.

In the hill districts of Manipur, nature rarely provides the opportunity of valley/plain based farming, therefore, 'slash and burn' and terrace farming is the only possible options. Shifting cultivation is extensively practised in uplands and crest areas. This traditional food production system, undulating terrain, and high and intense rainfall have further accelerated resource degradation and lessening processes leading to the whole forest ecosystem subside. Singh (2007) evoked that; land, water and vegetation are the three basic

resources of the life support system. These resources are under extreme pressure in the hill of Manipur characterised by the permanent conflict between the need for conservation on one hand and constantly growing population and land-use change on the other. With this, large forests area is reported loss. So, conservation and protection of forests are identified in the district. The effects of different forest land-use systems prevail in the district are little-known. The goal is to identify and document the present concept of the traditional ecological-based knowledge and practices of farmers regarding the environmental services of forest systems. The research expected to help improve the management of forests and benefit the community by ensuring enhanced forest sustainability.

Statement of the Problem

The problem can be viewed as the inter-relation of two systems, the forests and the stream. In these systems, the stream receives water released from the forest system, both during the rains but more significantly during the dry seasons. If the forests are of good canopy density, one may expect greater retention of moisture in the forest system, particularly through the mulches, root mass and soil absorption and then gradually released. Under clear-cutting or pronounced deforestation conditions, like shifting cultivation, the moisture retention is substantially reduced affecting any residual flow. The study obliges to assess how between these two systems are allied respects to flow exchange since a large literature exists augmenting the benefits of forests as a natural green dam. The objectives of the study are to assess the extent of forest cover loss and to assess the steam flow volume from two forest regimes in respect of the rainy season as well as the dry season. The research questions are broadly divided into two sections. The first issue relates to the process of deforestation and its relation to the variation in the seasonal stream flow volume. Secondly, it may be of significance to assess the impacts of anthropogenic disturbance (Jhumming) in a forest system to a possible decline in water availability as the importance of a healthy forest ecosystem in ensuring water resource is discussed worldwide.

Study Area

Senapati District is situated in the northern part of Manipur, bounded by Phek District of Nagaland in the North, Tamenglong district in the West, Ukhrul in the East and Imphal East and West in the South. It is located between 93°29' and 94°15' East Longitude and 24°37' and 25°37' North Latitude. It has a total geographical area of 3,271 sq km lies at an altitude between 1,061 m to 2,994 m above MSL. The district is under a humid subtropical climate with annual rainfall ranges from 670 to 1,450 mm. The district is home to many ethnic tribal communities with a population of 4, 79,148 persons and a density of 146 persons per sq km (2011 Census). They are traditionally and culturally mosaic with the distinct social systems of organisation and cultural beliefs.

Database and Methodology

Both primary and secondary data from diverse sources and types are employed. Collection of primary household data and empirical fieldwork database are the principal constituent module of this study.

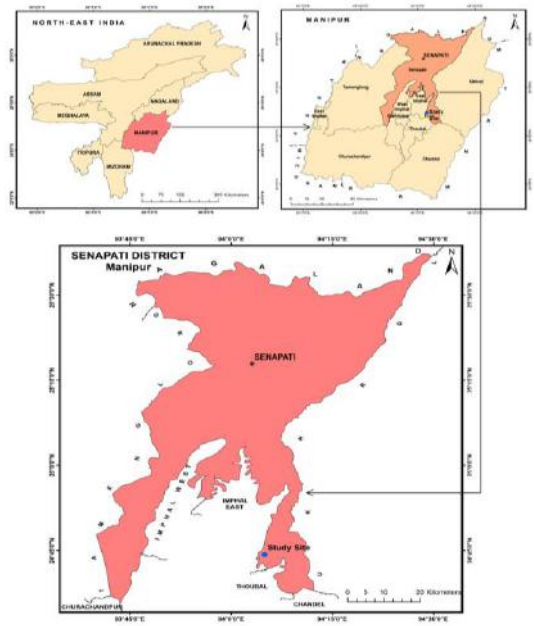


Fig. 1. Location of Senapati, Manipur

Forest Survey of India (FSI) 2009 to 2019 report; Manipur State Forest Department statistical data are incorporated to assessed district forest cover loss. Estimation of forest covers loss due to *Jhum* was done with data from the Forest Department and District directory. Statistical Year Book, 2015 published by the Directorate of Economics and Statistic, was the source of district decadal population growth, and decadal growth variation.

From 6 shifting cultivators' dominant villages, 100 households were surveyed for primary data. The traditional structured questionnaire method, as well as Participatory Rural Appraisal (PRA), was used to obtain information on economic pursuits undertaken by the *Jumias* in particular. A questionnaire with 36 questions is placed on every sample household/farmer. The socio-economic database was developed through interviews with traditional tribal chiefs, village authority leaders, age persons who could provide a holistic account of land-use dynamics in the field area. Stream flow data are collected through fieldwork.

Large numbers of papers have been documented on the significances of forests in regulating or providing stream water qualitatively or quantitatively worldwide. The present study is designed to investigate the functions of forest systems in providing stream water. The study involved the assessment of forest roles under two regimes (controlled and *Jhum* or degraded regime) forest land-use systems to that of the stream. To validate answers to the research questions or objectives, the forests system and stream are treated as separate systems. The flow of stream water was studied herein taking consideration of two identical rivulets of the varied source areas. The important research aspect is comparing streams flow volume for a two-year cycle.

A simple histogram was used to represent the trend in the forest cover. The changes or loss in the forest cover was evaluated with the help of USGS district's satellite images (2009 and 2019) using ArcGIS's applications for NDVI mapping. Simple Buckets method was used to assess stream flow volume. Separate monthly records series were maintained for each stream for both the wet and the dry season. Purposive Technique of Sampling was used in selecting among the *Jhum* cultivators covering every single village. Presentable data was prepared through SPSS and Microsoft Excel's statistical techniques.

Forests: Stream Sustainers

The first water function of the forest is to trapped rain and releases it down towards the valley. As it is in Senapati district, the influence of surrounding forests in providing water is commendable. On the other hand, it is also well established that partial or complete removal of tree cover may accelerate water discharge and increase flood risk and may reduce stream flow or even cause river beds to be dry out. A gradual depletion of forests and consequential degradation of soil and water resources of the traditional tribal habitat is stripping off their life-supporting capacities (Dash, 2005). The Senapati district of Manipur, inhabitants by various ethnic tribal communities represents a typical example. Fangyi and Jiading (2013) asserted that forests acting as sponges that soak up water during the monsoons and gradually release it (Maes et al. 2009) also purify water and regulate its flow.

Forest Cover Change Scenario in Senapati

Ethnic tribal communities in North East India are traditional forest dwellers. It is commonly believed that they live in harmony with nature and protect forests by considered as their livelihoods provider. As time changes, population increase and the need of people amplify escalating tremendous pressure on forest resources. In North-East India at least two-thirds of the forests are officially under the legal authority of local communities, while perhaps 90 per cent or more are physically controlled by rural communities. As in the hills of Manipur, the forest is governed by ancestral customary practices and beliefs. Illegal logging and forest conversion is more widespread where tenure rights over the forests are weak or unclear. This often linked to the absence of forest mapping and registration, as well as aggravated by laws and policies that are conflicting and constantly being challenged by private sector interests, government agencies, and even from within the communities themselves. With this fact, assessment of forest covers in tribal areas, therefore, acquires a special significance.

Table 1. Forest Cover Change Matrix of Senapati District

Year(s)	Total GA (km^2)	VDF (%)	MDF (%)	O.F. (%)	Total (km^2)	% of total GA	Net Change (%)
2009	3,271	7.12	28.73	34.54	2,303	70.41	
2011	3,271	7.12	26.59	33.01	2,183	66.74	-3.66
2013	3,271	7.09	26.32	33.01	2,173	66.43	-0.30
2015	3,271	7.01	25.12	34.42	2,177	66.55	0.12
2017	3,271	8.31	22.95	35.49	2,184	66.77	3.11
2019	3.271	8.25	22.74	34.27	2,136	65.32	-1.43
Total		1.13	-5.99	-0.27	-167		-2.16

GA-Geographical Area, VDF-Very Dense Forest, MDF-Moderately Dense Forest, OF-Open Forest
Source: *FSI, India State of Forest Report, 2009-2019*

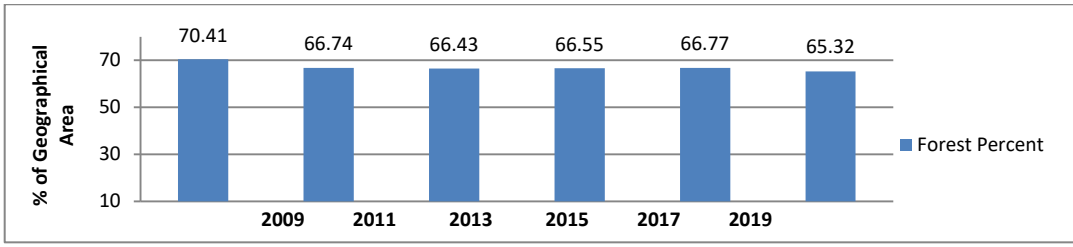


Fig. 2. Trend in Forest Cover

Source: *FSI, 2009-2019*

From Table 1: a gradual loss of forest area is noticed in which moderately dense forest areas degraded the most. Between 2009 and 2019, 5.99 per cent (196 km^2) moderate, and 0.27 per cent (9 km^2) un-classed open forest areas have been lost respectively. Due to the high rate of degradation in un-classes open forest, the district's land under scrubs increased tremendously. Till 2013, there are no scrubs land reported in the district but according to the recent 2019 report of FSI, an area of 287 km^2 is found under the scrub vegetation. Most significantly, the area under very dense forest is reported increased by 1.13 per cent (37 km^2). Geographically, 2,303 km2 (70.41 per cent) was under forests cover during 2009 and was reduced to 2,136 km2 (65.32 per cent) in 2019. The highest forest loss was recorded in 2011 that the district lost 120 km2 and loss10 km2 of its forest cover in the subsequent report. Increased in forests area has been detected between 2013 and 2017. Assessing gain and loss data, the district loss 5.10 per cent (167 km2) of its precious forests cover at the rate of 0.51 per cent (16.7 km2) per year. For a clearer picture, two years (2005 and 2015) NDVI satellite images on forest cover change are shown in Figure 3.

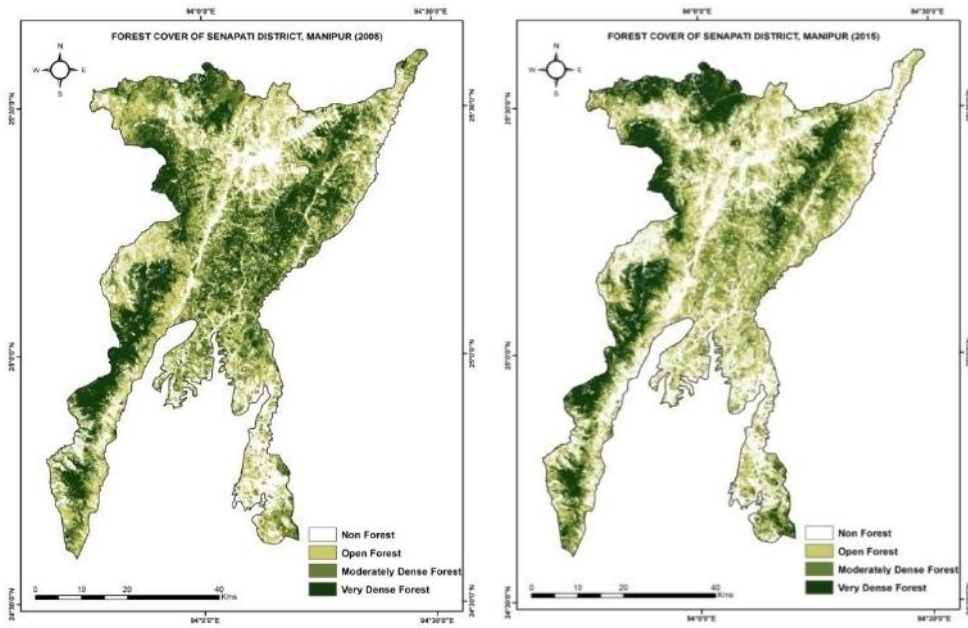


Fig. 3. Satellite Images Showing the Trend in Forest Cover (2005 and 2015)

Table 2. NDVI Data on Depletion of Forest Cover in Senapati

Variables (%)	Year (s)		Change (in %)
	2005	2015	
Non-Forest Area	24.09	33.41	+9.32
Total Forest	76.39	66.89	-9.5
Open Forest	50.3	51.6	+1.3
Moderately Dense Forest	37.7	37.7	-2.1
Very Dense Forest	11.9	10.6	-1.2

Source: *Analysing Satellite image*

Similar to that of FSI data, NDVI generated data provide more or less a similar depiction of forest loss (Table 2). The district forest area reduced from 76.39 per cent to 66.89 per cent signifying the 9.5 per cent loss between 2005 and 2015. The district's Non-Forest Area and Open Forest area improved considerably. The research disclosed that, between 2005 and 2015, the district lost 1.2 per cent VDF and 2.1 per cent MDF respectively. Form a generated database, a gradual shrinkage in the forest area is observed. Therefore, it is to say that, the district lost 9.5 per cent (i.e. 311km2) of its valuable forest area in just 10 years span at the rate of 0.9 per cent (i.e. 31 km2) a year.

Causes of Forest Cover Loss in Senapati

Population escalation and economic progress channel to trade-offs between diverse land use. A growing populace means an increasing demand for agricultural land and forest resources. Shah (2005); Yadava et al. (2002) claimed that, indiscriminate felling and destruction of trees and vegetation for firewood, timber and *Jhum* lands causes the highest loss of forests areas and eco-degradation in the North-Eastern state of Manipur. Since from the past many decades, a shortage of agricultural lands together with tremendous population growth has led to growing pressure on forests. Senapati District is the smallest hill districts of Manipur state yet recorded the highest decadal population growth. As the population increased, peoples start looking for new cultivable space or land for agriculture and settlement, eventually consequence of unprecedented pressure on existing forest lands. To begin with that, the district forests are not under the purview of the Manipur Land Records and Land Revenue Act, 1960, which was enacted to put some state's geographical areas in the government domain. The entire forest resource is owned and controlled according to customary laws and beliefs of individuals or community leaders. Approved utilisation or legal authority on forest resources or lands is vested upon the wisdom of the village chief or village council which is headed by him. This system of rightful power by individuals remains a stumbling block for the state as well as the central government agencies to check the misuse of forests resource. Similarly, creating different or geographical delineation of hills and non-hills area for effective social administration by granting certain constitutional provisions to hills people make complicated to control over the land or forest resources. The private ownership right of lands or forests resource endorsed the people to act promptly with no thought to large scale exploitation of forest areas. The age-old debates between the naturalists or the environmentalists' group with that of traditional tribal chiefs remain unsuccessful in efforts to preserve the forest areas in the district. From the above factual situation, one can point out that various anthropogenic activities are the reason for the extensive loss of forest covers in the district.

Demographics Dynamic of Senapati

The Senapati District is the most populated hill district of Manipur. It has a total population of 4, 79,148 persons (16.78 per cent of Manipur) with a density of 146 persons per km^2 (2011 census). Among the other hill districts; the district recorded the highest decadal population growth for the last five decades (Figure 4). Considered as one of the main factors for extensive loss of forest cover, the fast-growing population and its dynamic nature turn out to be important. For many decades, high population growth and unprecedented pressure on the forest resources have plagued the district. The district once home to 72,039 persons in 1961 become the dwelling of 4, 79,148 persons in 2011. It is increased at the average annual growth rate of 68.94 per cent (95,829 persons) per year. By 2021, it is projected that the district population would be 6.76 lace persons if the present growth rate is continued.

From Figure 5: a gradual increase is observed in the area under *Jhum* cultivation. The total *Jhum* area of 0.83 thousand hectares during 2013 was amplified to 3.42 thousand hectares in 2017. As per the finding, the district forest covers have been degraded annually at a pace of 7 km2 by *Jhum* or similar related activities.

To draw the traditional knowledge and implications on forest questions were prepared which are important to the study. The information acquired as shown in Figure 6 reflecting various variables put up for the query. Essentially, out of the total 100 farmers, 98 of them (98 per cent) are said to be using stream water for crop farming activities, 90 per cent agreed with forests as an ultimate source of required water most importantly during the lean season and 73 per cent 'yes' with the cutting of trees deplete water resource. The consequence of deforestation are manifolds, perhaps, the Jumias or terrace cultivators in the study area agreed to the erosion of soil, water shortage, drying up of streams, soil unproductiveness, abandoned of fields, the crops yield or production decline are the results of forest degradation.

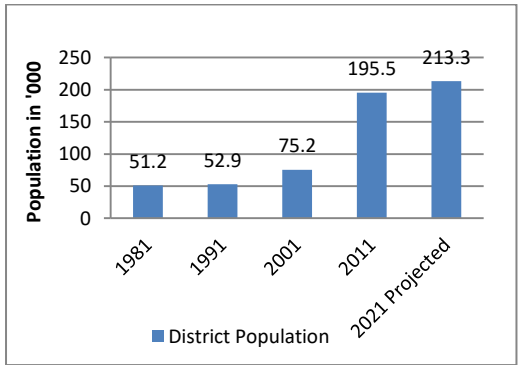


Fig. 4. Decadal Poplation Growth Variation

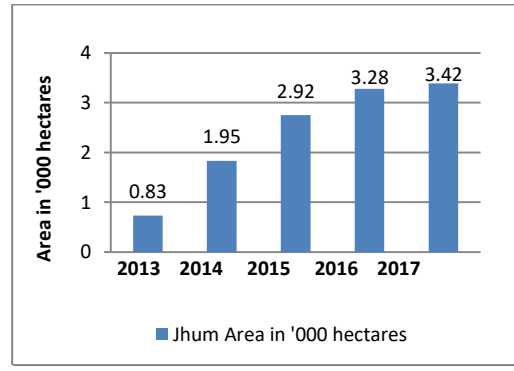
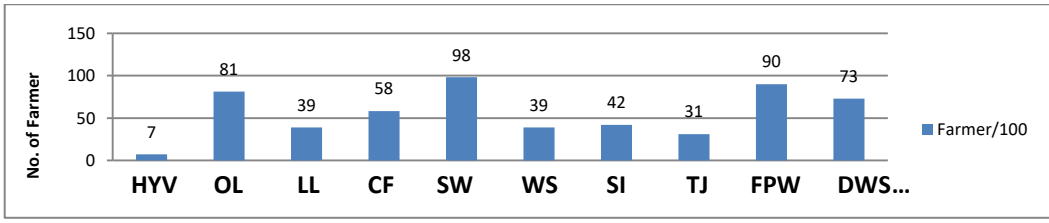


Fig. 5. District Rice Area under *Jhum* Cultivation

Source: Directorate of Economics and Statistics, Manipur, 2018



(HYV=High- Yielding -Variety; OL=Owned Land; LL= Leased Land; CF= Chemical Fertilizers; SW= Streams Water; WS=Water Shortage; SI=Soil Ingresses; TJ= Terrace and Jhum; FPW= Forest Provide Water; DWS=Deforestation cause Water Scarcity)
Source: *Field Survey, 2017*

Figure 7 shows the distribution of the annual household income from all types of sources. Out of the total 100 households, 29 generate Rs. 41-50 thousand; 28 generate Rs. 51-60 thousand; earned above Rs. 70 thousand respectively. Interestingly no farmers earned below Rs. 20 thousand. From the analysis, highly irregular income flow is observed in society.

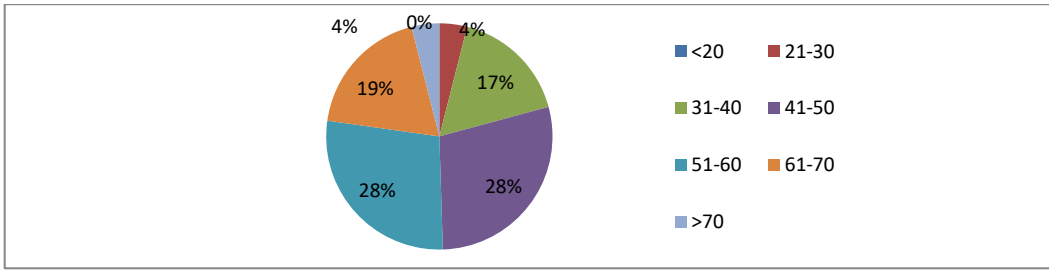
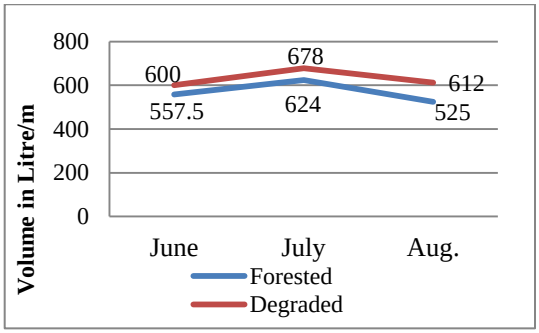


Fig. 7. Annual Household Income in '000 Rupees
Source: *Field Survey, 2017*

Results and Discussion

To identify the implications, the experiment was carried out upon two streams of similar morphology with having different source regions; controlled forested stream and *Jhum* or degraded forests stream. Three months flow data series records were maintained both for the wet as well as the dry season. Relative average stream flow volumes for both the seasons during the two-year cycle were given in the figures below: It is clear from (Figure 8 and 9) that, the two streams emit different flow pictures. Dry season measurement on the same streams gave diverse information that only forested stream coupled with a flow. In comparing average flow volumes of two-year-cycle considerable flow variation was observed in both the cases. It is identified that the forested stream with an average volume of 557.5 L/m during the month of June (2016/2017) recorded 13.9 L/m during January (2017/18). In the same fashioned, the average flow of 624 L/m during July (2016/17) reduced to just 12.6 L/m in February (2017/18) and so on. According to (Figure 8), the average volume of a degraded stream during the wet months recorded 600, 675 and 612 L/m respectively. The unusual striking experience was that the degraded forest stream which was records higher turbidity flow during the wet season is seen without flow during the dry season (Figure 9). It is assumed that the availability of flow even during the dry months as a hydrological function of the forest.



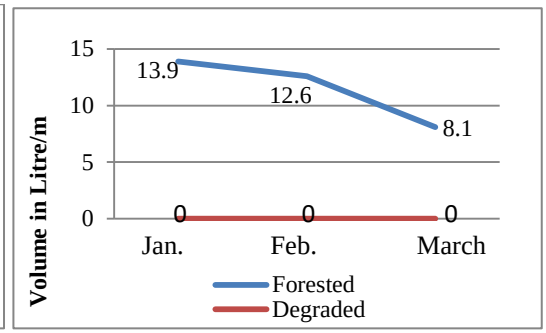


Fig. 8. Wet Season Average Flow Volume **Fig. 9. Dry Season Average Flow Volume**

Source: *Fieldwork, 2017-2018*

(To avoid any inconsistency, flow measurement during the wet season was done on the same date i.e. 22nd of June, July and August, 2016/2017 and that of the Dry season on the 9th of January, February and March, 2017/18. The stream volume was collected for 3 sec and calculated for 1 minute in an analysis. During the dry season 2017/2018, the degraded forest stream is found completely dried out)

Findings

- A gradual loss of forest cover was noticed in the district losing a total of 306 km^2 at the rate of 30.6 km^2 annually (FSI, 2009-2019).
- The traditional *Jhum* cultivation, rotational felling, population pressure and uncertain land tenure system are the major factors causing forest degradation in the district.
- A controlled forest able to provide water needs through the stream or spring throughout the year which was not in the case of disturbs stream.

Conclusion

Senapati District is the most populated hill district in Manipur. The district forests today are more threatened than in the past; owing to the increasing population pressure. An alternative livelihood or incentive must be provided to the farmers/Jhumia/villagers who depend on forests to minimise the degree of dependency. The identification of the degraded areas and regenerating such notified areas through Joint Forest Management programmes must be encouraged. The community responsiveness and awareness campaigns will only help to fight or disseminate the ecological significances of forests. Katerere and Smith (2013) local communities are often the custodians of ecosystems and therefore are critical actors in sustaining natural resources and managing conflict over them. To this context, the greatest threat to the preservation of the forests ecosystem comes from marginal farmers in the Senapati District of Manipur. Arguably the only sure way of stopping deforestation is to minimize, and eventually, to eliminate, the territorial demands made upon the forests by thousands of *Jhum* cultivators. The study found out that, lack of proper institutional and legislative framework in managing forests and lack of definition of rights, control of territories, the vague ownership over forests, and lack of survey and settlement operations are seen as the root cause of forests shrinking in the district.

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IMPACT OF ITHAI BARRAGE ON LOKTAK LAKE AND ITS SURROUNDING AREA

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Abstract

Wetland, the world's key normal asset which is the progress among land and water confronted a genuine danger everywhere throughout the world. Loktak lake, the Kohinoor of Manipur has faced as serious change with the establishment of Ithai Barrage in 1983. Using remote sensing indices such as Normalised Difference Vegetation Index (NDVI) and Normalised Difference Water Index (NDWI), this paper studies the impact of Ithai barrage on Loktak lake. It is found out that it flooded the agricultural land surrounding the lake. The disappearance of indigenous fishes, the disruption of seasonal floating and sinking of the Phumdies in the Keibul Lamjao National Park, the increase siltation rate of the Loktak lake has affected the Loktak lake to a great extent. If this process still prevails, the precious Loktak lake, in the near future will perish from the earth. So, the only option to save is to decommission Ithai barrage.

Keywords: Loktak lake, Ithai Barrage, NDVI, NDWI, LULC

Introduction

Man has been changing the substance of the earth in his mission to satisfy his avaricious needs. Through his endeavours for a boost of assets, man has been adjusting the earth since the beginning of human civilizations either intentionally or unknowingly. Everything is associated with everything else and can't change only one thing in nature (Peter, 2001). Consequently, change of one part in nature modifies different segments. Despite these, people don't stop or are set up to end it in the days to come. This ruinous economy shows shifted of occasions or wonder, for example, desertification, water-logging, and so on. Artificial dams or barriers are one anthropogenic ecological evolving marvel. Water is the most broadly utilized and irreplaceable common asset. Other than different uses in our everyday lives, water system, industry, and transportation, it is utilized for producing hydro-electric force. For quite a long time man has saddled the intensity of running water to help him in his work. As of not long ago, he knew just the immediate technique for utilizing it by having a quickly moving stream turn a water wheel. A wheel was set in a characteristic cascade, where the water could drop straightforwardly on it. In certain spots, dams made a counterfeit cascade, beat the water, and balanced the stream. Water power utilized along these lines assumed a huge job in the improvement of assembling in a few pieces of the world.

Wetland, the world's key normal asset which is the progress among land and water confronted a genuine danger everywhere throughout the world. Thusly, Loktak lake, the Kohinoor of Manipur just as the biggest new water lake in northeastern India has confronted a genuine environmental and morphogenetic change with the development of the Ithai Barrage Dam which was built in 1979 on the Imphal River as a component of the National Loktak Multipurpose Hydroelectric Project (1983) with the end goal (Roy et al, 2019) of the water system and force age (North East Wetlands Review, 2017). It was introduced to create 105 megawatts of power; watered 24,000 hectares of land; gain Rs. 20-30 crores as state income and upgrade monetary turn of events. Be that as it may, the planners didn't consider the perplexing seepage design and the delicate biological system (Tombi, 2018). They understood that the lake didn't have profundity to produce power (Ghosh, 2018). Thus, they needed to commission the Ithai Barrage further down the Imphal River. The elevated level of water in the lake is flooding the encompassing territory. It immersed agricultural land more than double the territory it proposed to water, evacuated, and denied around 10,000 individuals of their job. The development of the plant has compromised the delicate environment which supports more than 1 million individuals. Since its origin, around 20 amphibian species have vanished, the population of transient flying creatures and waterfowls have dwindled and the main living space (Phumdis, 2020) of the Sangai (Indian Dancing deer) is nearly annihilation.

With the water level now for an all-time high, *phumdi* can no longer reach at the lake bed in the dry season (Mohanty, 2008). Incapable to benefit from supplements, Loktak's islets of vegetation are dispersing and decayed lumps sink in. With the Ithai Barrage hindering the outlet that once associated the lake to the ocean, people can't discard the perishing biomass any more. Along these lines, throughout recent decades, spoiling vegetation has been accumulating on the lake bed. Run-off from encompassing agrarian fields has added pesticides and bug sprays to the blend. At long last, the Nambul river that streams from Imphal into the lake dumps in it the untreated sewage of a whole city. This has brought about an extreme development of semi-oceanic weeds that drain oxygen in the water, gagging the Loktak Lake (Mohanty, 2008).

The torrent has hindered the course of transient fish coming into the lake from Myanmar thus Loktak, at this point cannot satisfy the need of a whole State. In an offer to save from the circumstance, the fisheries office presented one lakh fishes got from Andhra Pradesh and Odisha. This has become a yearly custom now, one that has progressively cleared out a few types of *fabou nga* (local fish) found in the lake (Mohanty,2008) This paper analyses the LULC (Landuse and land cover), NDVI (Normalised Difference Vegetative Index) and NDWI (Normalised Difference Water Index) of the two points of time 1977(Pre Ithai), 1998 and 2020 (Post Ithai) of Landsat 2 MSS and Landsat 8 OLI/TIRS for the gap of 21.2 years and contemplate the impact of Ithai barrage on Loktak lake and to the people.

Study Area

Loktak lake, the precious gem of Manipur is the largest freshwater lake in the North East and is famous for its floating weed covered with soil called *phumdies*. It is located in

the Bishnupur District, Manipur. It's spatial extend is $24^{0}33/$ N and $93^{0}47/$E with the surface area of 273 square kilometres. It is also the home of the famous deer called Sangai. It was designated as a wetland on 23rd March 1990 by Ramsar site no. 463. However, with time, Loktak lake faced a multitude of the change mainly by the establishment of Ithai barrage in 1979 with the hope to generate power has affected the ecological regime to a great extend. As might discuss the increases in siltation rate, decrease in vegetation, loss of precious fish, thinning of *phumdies*, increase in the superficiality of the lake are the main problem faced in the Loktak lake. The increase in the superficiality has to lead to the inundation of agricultural land ultimately displaces the people.

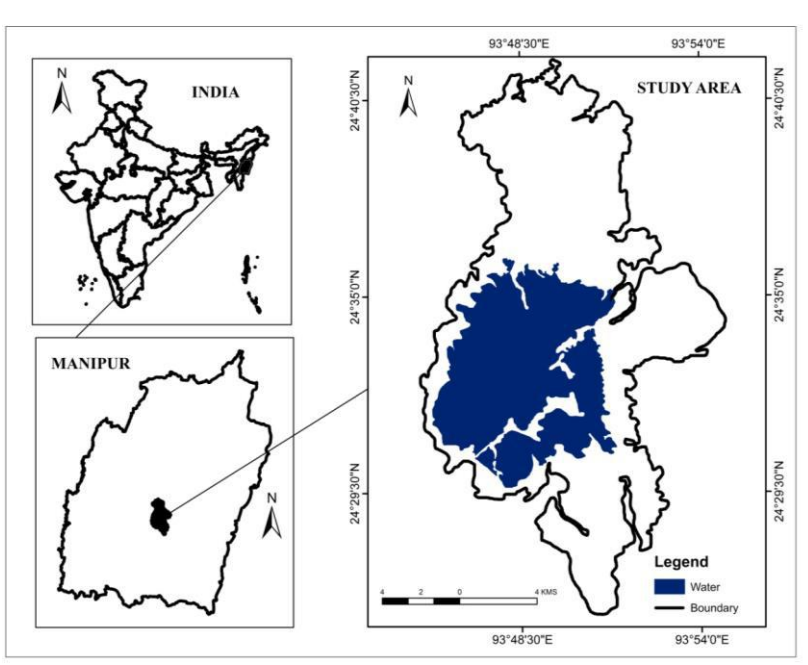

Fig. 1. Location of Loktak Lake

Database and Methodology

Being downloaded the georeference Landsat 2 MSS and Landsat 8 TIRS/OLI images of 1977 and 2020 are from the USGS site, they are being stacked in Erdas 9.1 to get a composite image except for the panchromatic image (for 2020) and thermal images. The dates of both the images are been as about as conceivable in a similar vegetation season. The subsets of the study area are being reckoned from the composite images. The Landsat 2 MSS image consists of several scan line errors that are being resolved using Landsat toolbox on ArcGIS 10.3. To fulfill the research, some prominent indices such as NDVI and NDWI are being used in this research. However, to adjust to the research, some modifications have been made to NDVI as the normal formula for calculating the index doesn't fulfill in the analysis of the Landsat 2 MSS image. The formula is being generated by observing minutely the spectral response pattern of several features.

Landsat 2 MSS

NDVI= (NIR-RED)/ (NIR+RED)
NDWI= (GREEN-NIR2/ GREEN+NIR2)

Landsat 8 OLI/TIRS

NDVI= (NIR-RED)/ (NIR+RED)
NDWI= (GREEN-SWIR1)/(GREEN+ SWIR1)

Before the image classification, image enhancement procedures, for example, histogram equalization, radiometric correction is done keeping in mind the end goal to enhance the perceivability and interpretability of the images. The accessible auxiliary wellspring of information including research articles, government publications, books is being gathered.

Image Classification

Each distinctive feature is identified by using different band combination methods among which the Standard False Colour Composite (Std. FCC) is the most efficient. Out of which, 5 features for 1977, 1998 and 2020 image are identified and classified using USGS scheme but has been modified to suit the local context such as Agricultural land, Built-up land, Water, Thick Phumdies, and Thin Phumdies (Phumdies: A heterogeneous mass of vegetation, soil, and organic matter at various stages of decomposition–Phumdi, 2020). The subset images are compared and classified using Interactive supervised classification on Erdas 9.1 independently.

Results and Discussion

Accuracy Assessment

About 75 points are taken for each of the 3 pre-classified images of 1977, 1998 and 2020 in order to render access the classification accuracy for the classified images. 2 shows the error matrices of classified images which includes Producers Accuracy, Users Accuracy as well as Overall Classification Accuracy and Overall Kappa Statistics. This creates some difficulties in the distinction and differentiation between built-up land and agricultural land as they experience the same spectral response pattern during this season. The main reason is due to which the agricultural land is left fallow during this season. Thus, the classification is not highly accurate. Even so, the classification made is the best classification among many classifications (Figure. 2). When analysing the two points of time i.e. 1977, 1998 and 2020, built-up land shows the consistent increase in the spatial extent followed by waterbodies (Table 1). The built-up land spread out at the periphery of the study area. But when compared to the northern side (Figure 2). A large number of agricultural land had been submerged after the Ithai barrage has been commission due to the withholding of water for the generation of electricity at the Loktak project. The sediment to be carried away but the Imphal river has been diverted to the Loktak lake via Khodrak river which is supposed to be carried away by Khodrak river. Besides, the increase in deforestation and an increase in the soil erosion has to lead to the higher siltation of Loktak lake thereby increased in the water level.

Thus, the conversion of paddy field to some fishery farm to suite the ongoing condition has been commonly seen in the study area. Above all the conversion of Thin Phumdies to the fish farm is a common trend in the study area. The easy availability of water and as well as the naturally occurring Phumdies acts as a perfect choice for a fish farm. This is the main reason for the increase in water bodies and the value of NDWI (Figure 4) and a decrease in NDVI for the three periods of time (Figure 3). When NDWI has closely assessed the waterbodies of Loktak lake has been increased considerably mainly on the eastern side of the lake. Above all the northern side signifies the largest increase compared to the southern side.

Table 1. Spatial Coverage of LULC Features in Hectares

Features	1977	1998	2020
Agricultural land	6,046	3,241	5,046
Built-up land	1,664	2,091	4,985
Thick Phumdies	1,889	2,246	2,041
Thin Phumdies	8,046	9,067	3,413
Waterbodies	4,513	5,513	6,673
Total	22,158	22,158	22,158

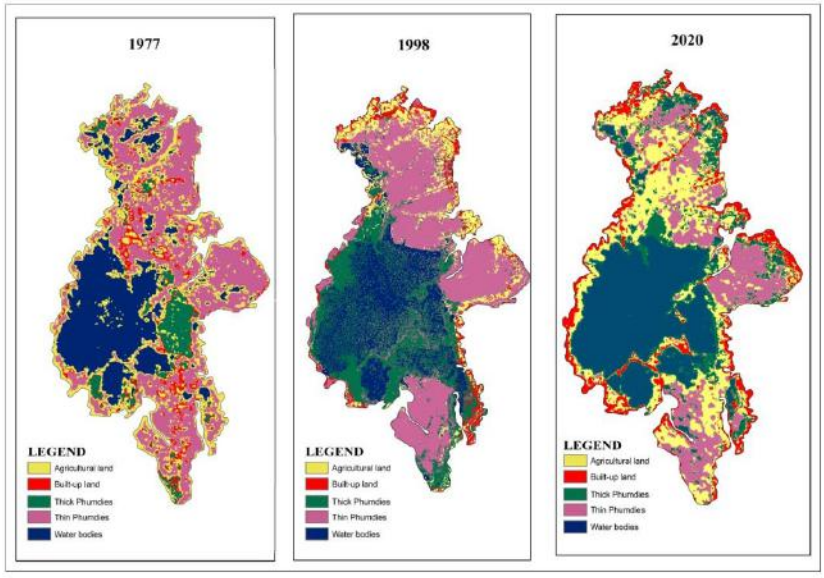

Fig. 2. LULC of 1977(Pre-Ithai), 1998 and 2020 (Post Ithai)

The development of the Ithai Barrage is an important component of Loktak Hydropower Project and has a broad impact on the social and physical condition of the lake and its owners. Individuals living in the lowlands along the waterways of the Loktak and Manipur rivers have visited the floods in view of the implications, breach and associated factors of the silt and watershed. The spread of vegetation in the catchment area along the shore of the lake and the development of the Ithai barrage have posed major problems for the multipurpose development of the Loktak lake and its areas. Degradation of the catchment (Phumdi, 2020).

Table 2. Accuracy Assessment

1977					
Class Name	**Reference Totals**	**Classified Totals**	**Number Correct**	**Producers Accuracy**	**Users Accuracy**
Agricultural land	43	41	40	93.02%	97.56%
Built-up land	4	3	3	75.00%	100.00%
Thick Phumdies	7	7	6	85.71%	85.71%
Thin Phumdies	19	22	17	89.47%	77.27%
Waterbodies	9	2	1	50.00%	50.00%
Totals	75	75	67		
Overall Classification Accuracy = 89.33%, Overall Kappa Statistics = 0.8224					
1998					
Class Name	**Reference Totals**	**Classified Totals**	**Number Correct**	**Producers Accuracy**	**Users Accuracy**
Agricultural land	38	40	36	94.74%	90.00%
Built-up land	2	3	2	100.00%	6667.00%
Thick Phumdies	11	8	8	72.73%	100.00%
Thin Phumdies	19	21	18	94.74%	85.71%
Waterbodies	5	3	3	100.00%	100.00%
Totals	75	75	67		
Overall Classification Accuracy = 89.33%, Overall Kappa Statistics = 0.8335					
2020					
Class Name	**Reference Totals**	**Classified Totals**	**Number Correct**	**Producers Accuracy**	**Users Accuracy**
Agricultural land	25	24	23	92.00%	95.83%
Built-up land	10	12	10	100.00%	83.33%
Thick Phumdies	32	28	28	87.50%	100.00%
Thin Phumdies	7	10	7	100.00%	70.00%
Waterbodies	1	1	1	100.00%	100.00%
Totals	75	75	69		
Overall Classification Accuracy = 92.0%, Overall Kappa Statistics =0.8857					

Deforestation and transfer of irrigation in the catchment areas have accelerated the process of soil erosion about the surface of the lake due to soil extinction. Annual precipitation in the lake is 336,325 tons (Caverna, 2007). From the city of Imphal to the Nambul River, the catchment area and domestic wastewater supplements are released into the lake, which affects its water quality, as well as in the encouragement of the growth of water hyacinth plants. Each of these activities has a direct impact on the lake's biological strength. Interference in navigation and overall aesthetic value of the Lake are other reported adverse effects. The development of the Ithai Barrage and the maintenance of sustainable water levels at the Full Supply Level (FRL), affecting the biological processes and aspects of wetlands, immersion in rural areas and displacement and loss of individuals from highly affected areas have led to advances in hydrological systems, fish population and diversity. A recent examination of the concentration of some components showed high concentrations of nitrate in all areas beyond the inadequate permissible range for drinking (Kongbaum et al., 2017). To a limited extent, lake water is relatively new to the original pollutants. Thus the thickness of the Keibul Lamjao National Park has been reduced, which can interfere with the resettlement of the Sangai deer and fish rehabilitation from Myanmar's Chindwin-Irrawaddy River system.

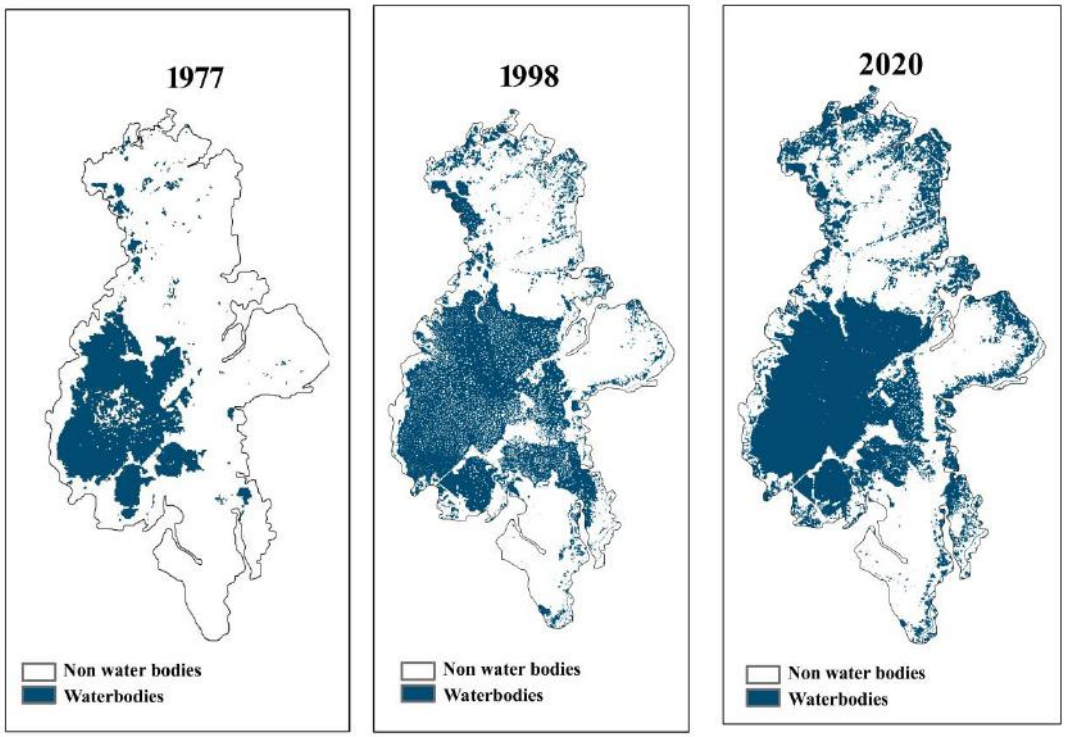

Fig. 3. NDWI for 1977 and 2020

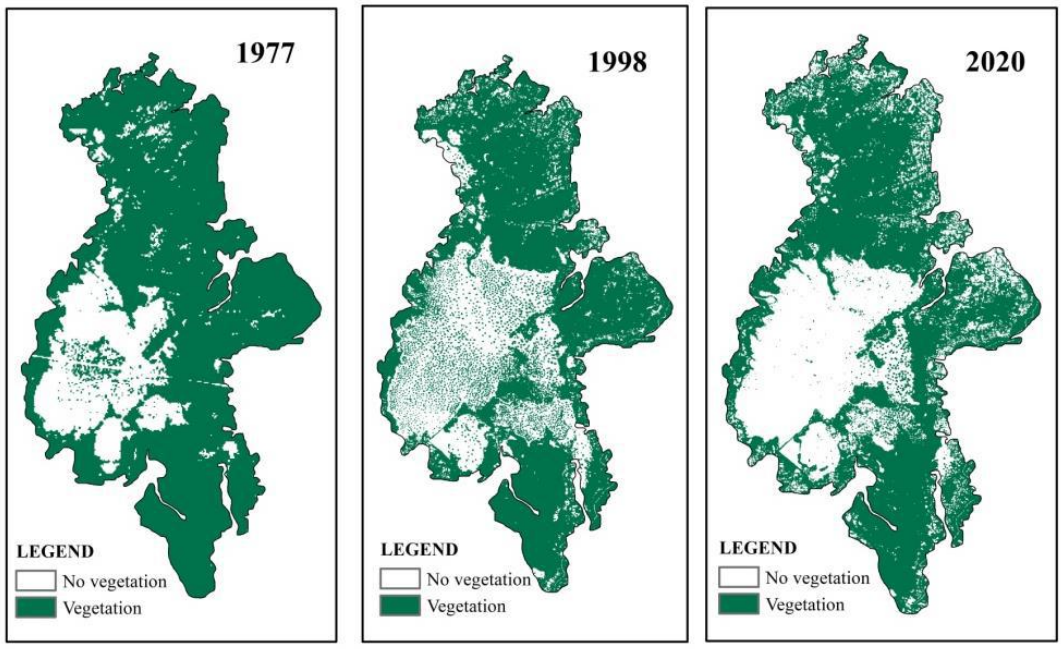

Fig. 4. NDVI for 1977 and 2020

Various economic plant populations, for example, saccharine species, *Cetaria pumila, Alpinia nigra, Hedricium spicatum*, and important food plants such as Zizania, Latifolia, Carax species, have caused starvation conditions for the *sangai* deer (Phumdi, 2020). Due to the thinning of the lungs, the legs of Sangai's appendix become swamped and they sink. Reduced production of foodstuffs from lotus plants (Thomchet and Tambou) Plants are additionally discussed due to contaminated water (ENVIS, 2007).

Loktak has forced the issues of the loss of biodiversity the populaces' transitory and occupant waterfowl has declined during the most recent couple of decades because of poaching and changes in biological character (Laithangbam, 2019). The natural surroundings Sangai deer in Keibul Lamjao National Park (KLNP) is likewise undermined because of diminishing of *phumdis* and poaching, 35 species (5 warm-blooded animals, 3 winged creatures, 9 reptiles, 3 creatures of land and water, 12 fishes, 2 molluses and 1 annelid) that were accounted for to be bounteous in the past have declined and are presently vanishing gradually. Loktak Lake is the lifesaver of the Manipur. Loktak Lake used to be the wellspring of food plants of the individuals. Heikak, tharo (Nymphaea pubescens), thambal (lotus), thanging, ikaithabi, ishing kundo are a portion of the significant food plants (Jugindro, 2017 and Roy, 2019). The greater part of this plant species have withdrawn in light of the adjustments in the water level of the lake, contamination, and different components of the lake's environment and ecology. The stagnation of water builds the rate of pandemics. Plus, it causes million tons of sediment deposited into the beds of the lake that are brought down from the encompassing slants during the rainy seasons, thereby the holding limit is enormously decreased. It additionally causes expanding contamination content into the lake water and its common beauty. In short, the task lessens the inherent just as its extraneous worth, along these lines turning into the sobriquet "the Sorrow of the Loktak Lake.

With the developments of the barrage, agricultural land experienced an extensive change incongruity with the changing scene caused by the ascent in water level. Be that as it may, the settlement designs when the venture appears to be uniform with the exception of the extension of the settlement zone to some length. This may due to the expanding populaces of the considered region. With the development of the Loktak Hydro Electric Project, the majority of the rural fields are changed over into fish farm aside from in some territory of the western part of the examination region. In any case, before the undertaking, there was no fish here. Considering overall, the majority of the pilgrims detailed that they don't get enough comes back from the transformation of their agrarian grounds to fish farms because of the consistent danger of flooding past the dike level, which makes the fishes stream out from the edge of fish farms.

In addition, these issues have straightforwardly or in a roundabout way mindful by National Hydro Electric Power Project for influencing the lives of more than one lakhs individuals living in and around the lake, who are relying on the regular assets of the lake for consumption. The issues looked by the fisherman because of the debasement of Loktak Lake are the following: The fish get has radically diminished since the water level of the lake remains continually high, the fisherman needed to depend on adjusted Athaphum

angling practice. The Loktak has in danger from quick multiplication of weed. Development of weed has secured in excess the water surface zone, subsequently obstructing the pathways of fishes. The development of the weed by wind obstructs the route.

Conclusion

With the establishment of Ithai barrage, there are a few merits, for example, the protection of lake and preservation of water, activity of intensity, water system offices, the flexibly of water for Loktak downstream, however it has been overflowed with a progression of negative marks which have a genuine of effect on the earth. It overwhelmed the agrarian land encompassing the lake. The vanishing of indigenous fishes, the disturbance of regular gliding, and sinking of the Phumdies in the Keibul Lamjao National Park, the expansion siltation pace of the Loktak lake has influenced the Loktak lake to an extraordinary expansion. In the event that this process despite everything wins, the valuable Loktak lake sooner rather than later will be extinct from the earth. So the only option in order to save Loktak lake is to decommission the Ithai barrage.

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GEOCHEMICAL ANALYSIS OF GROUNDWATER IN NOYYAL RIVER BASIN, TAMIL NADU, INDIA

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Abstract

Noyyal basin is one of the active river basins in Tamil Nadu that involves several industrial and agricultural activities. These activities significantly play a crucial role in the deterioration of both surface and groundwater quality. Here, a study is made to analyse the physico-chemical parameters of the groundwater in the Noyyal River basin. The quality of groundwater is analysed based on its physical and chemical parameters. The physical parameters of the groundwater were analysed with Potential of Hydrogen (pH), Electrical Conductivity (EC), Total Dissolved Salts (TDS) and Total Hardness (TH). Chemical parameters were assessed based on its major cations of Calcium (Ca), Magnesium (Mg), Sodium (Na) and Potassium (K) and anions of Chloride (Cl), Sulphate (SO4), Nitrate (NO3) and Bicarbonate (HCO3). These analysed parameters were compared with the standards of the World Health Organisation (WHO) and the Bureau of Indian Standards (BIS) for drinking purposes. Geographic Information System (GIS) was utilised to find the spatial distribution of the selected parameters. The outcome of the study shows that the collected groundwater samples are hard and saline in nature. The concentration of calcium, magnesium, sodium, and chloride in the collected samples was not meeting the prescribed standards for drinking. The study reveals that most of the groundwater samples are not under suitable ranges for the consumption of human beings. The spatial information reveals that the central and eastern part of the basin's groundwater quality parameters such as electrical conductivity, total dissolved salts, sodium, calcium and chloride values are found to be above the prescribed limits and not fit for drinking purposes.

Keywords: Physico-chemical parameters, WHO, BIS, GIS, Drinking purposes

Introduction

Water is one of the precious natural resources for which more concerns is given all over the world. Water and sanitation are under the sixth goal of the United Nations Sustainable Development Goals (UN SDG's). Absence of reliable source of freshwater in terms of both quality and quantity is gliding over all parts of the earth (Saraswat et al., 2019). Growing demand, disparities in water supply, insufficient knowledge and resources, major land-use transformations, the decline in the water table, an increase in water contamination are the major causes for the water crisis on the earth (Datta, 2005). Due to

the degradation of water quality, available water resources are becoming unsuitable and dangerous for human consumption (Saraswat et al., 2016). Potable drinking water is free from disease-producing micro-organism and chemical substances (Shittu et al., 2008). The quality of groundwater is mainly determined by lithological factors, hydrological and chemical processes of an area. It is also determined by anthropogenic activities such as agricultural, industrial and domestic activities. The cations and anions play a substantial role in determining the quality of water for drinking purpose. If it exceeds the permissible limit, it leads to some health risks to humans. By checking the water quality, it can be easy to understand the ion concentration, which can be further made into proper treatments for better use. GIS is a useful tool that could be used for developing solutions for problems related to the assessment and management of water resources. GIS not only provides an excellent platform for visualisation but also helps to analyse and understand the existing scenario of the assessing unit.

Groundwater decline, insufficient rainfall and continuous extraction of groundwater for agriculture, industries and drinking purposes lead to desertification in several pockets of South India (Kumaraswamy, 2003). Most of the rural people don't have the access to potable drinking water and they are highly depending on wells, streams and rivers for domestic purposes (Devi and Premkumar, 2012) The river basin is the optimum environment or the best unit for analysing spatial, seasonal and secular variations in the chemical characters of the groundwater studies (Sivagnanam and Kumaraswamy, 1983). Here, the Noyyal River basin is chosen as a study area to analyse its groundwater quality based on physico-chemical parameters.

Study Area

The location of the Noyyal basin extends from 10º54' to 11º19' north latitudes and 76º39' to 77º55' east longitudes. The basin is situated in the western part of Tamil Nadu, India (Figure 1). It covers an area of nearly 3500 sq.km. Noyyal River is one of the tributaries of River Cauvery which passes through the districts of Coimbatore, Tiruppur, Erode and Karur. The Western Ghats borders the western part of the study area, the northern and southern boundaries of the basin are shared by Bhavani and Amaravathi basin, respectively. The lithology of the basin varies from old Archaean rocks to recent Cainozoic sediment deposits. The significant landuse of the basin is agricultural land and urban built-up land. The basin possesses high urban population than the rural population. Industrial and the agricultural activities are the two important occupations of the people in the basin.

Database and Methodology

A field investigation has been conducted during June 2018, and 48 groundwater samples were collected from the Noyyal River basin. The physical parameters of pH, EC, TDS were measured at the time of sample collection in the field. These samples were stored in a clean plastic container and labelled appropriately with its location and other primary information. The collected groundwater samples were transported to the laboratory

for analysing its chemical parameters. The concentration of calcium, magnesium, bicarbonate and chloride were estimated by Ethylene Diamine Tetra Acetic Acid (EDTA) Titrimetric method. Sodium and potassium estimated by using Flame Emission Photometric Method (FEPM). Nitrate by Ultraviolet-Visible (UV–VS) Spectro-Photometer method, sulphates by Turbid metric method. The results obtained from the analysis were compared with the WHO and BIS standards (Table 1). The spatial distribution of the physical and chemical parameters is generated using interpolation technique with the tool of Inverse Distance Weighted (IDW) in ArcGIS 10.1 software. (Figure 2, 3 and 4)

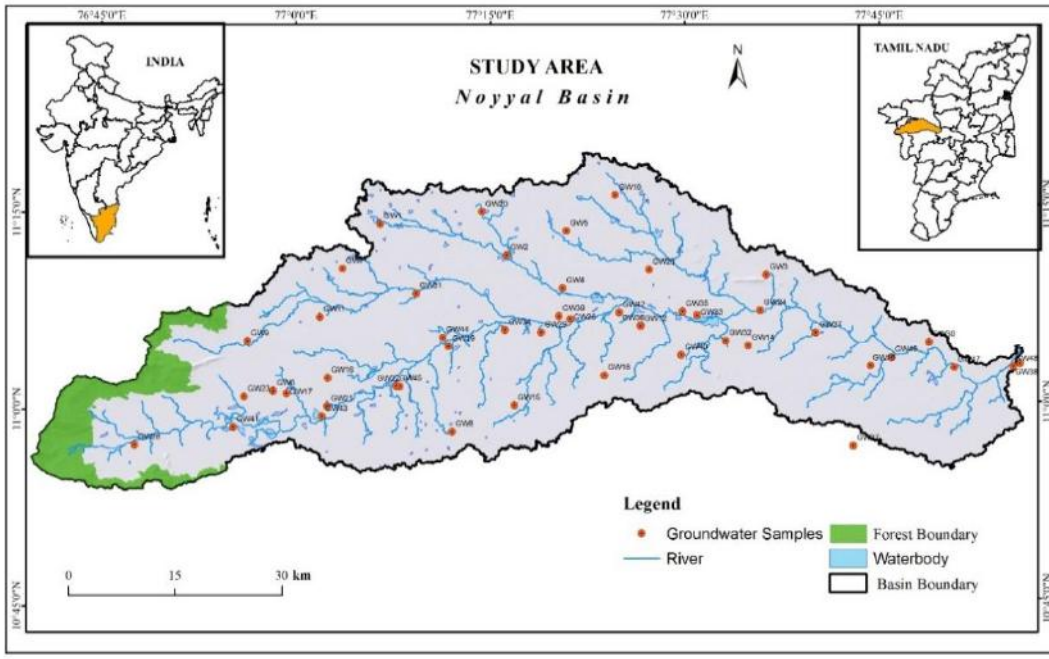

Fig. 1. Location of the Study Area

Table 1. Drinking-Water Standards of WHO and BIS for Physical and Major Chemical Parameters

Physical and Major Chemical Parameters	WHO (2004)		BIS (1986)	
	Desirable	Permissible	Desirable	Permissible
pH	6.5-8.5	-	6.5-8.5	-
EC	400	1,400	No Guideline	No Guideline
TDS	500	1500	500	2,000
Hardness	100	500	300	600
Ca	75	200	75	200
Mg	30	150	30	100
Na	200	-	No Guideline	No Guideline
K	20	-	No Guideline	No Guideline
SO_4	200	250	150	400
NO_3	40	50	45	100
Cl	250	600	250	1000
HCO_3	No Guideline	No Guideline	No Guideline	No Guideline

Results and Discussion

Physical Characteristics of Groundwater

Potential of Hydrogen

The potential of hydrogen (pH) is the primary measure of groundwater quality which is termed as a potential hydrogen ion concentration of water. Water with pH value seven is neutral; less than seven is acidic, and greater than seven is alkaline in nature. The value of pH in the basin is ranging from 6 to 8.23, with an average value of 7.83. About 54 per cent of the samples are alkaline, and 46 per cent of the samples exhibit acidic nature of water.

Electrical Conductivity and Total Dissolved Salts

Electrical conductivity is one of the significant parameters that measure the concentration of ions in the water. Water with high salt content will have high conductivity. The value of conductance in the study area is varying from 78.2 to 14569 µS/cm, and its average is 3762 µS/cm. The basin possesses high electrical conductivity that infers the groundwater samples are highly saline in nature. The total dissolved salts are measured in terms of mg/l. The concentration TDS for the collected sample varies from 55 to 9470mg/l, and its average concentration is 2497mg/l.

Hardness

Calcium and magnesium concentrations contribute hardness to the water. There is no severe health hazard due to the hardness in water. However, it has effects in washing cleaning utensils, electrical equipment, etc. The hardness in the basin is ranging between 302 to 6200mg/l with an average of 1247mg/l. All the collected groundwater samples possess very high hardness.

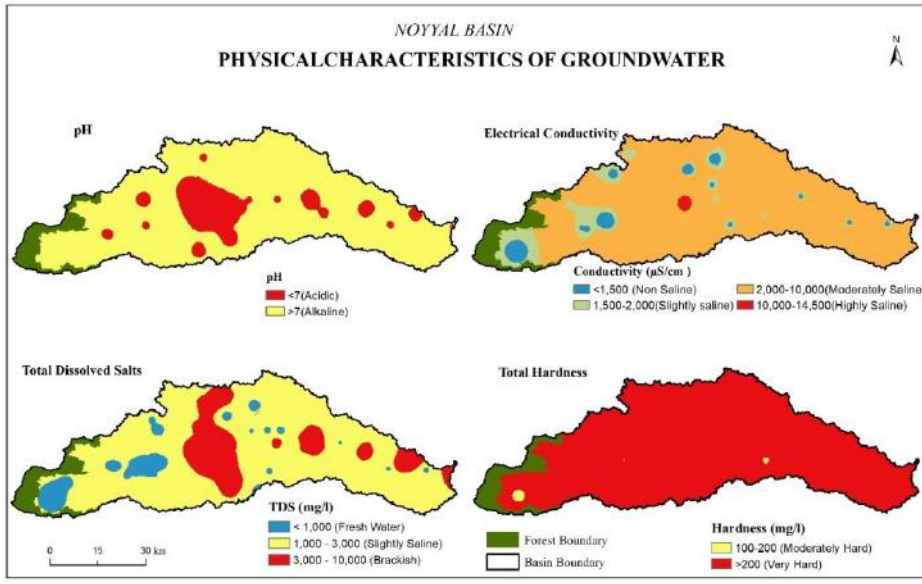

Fig. 1. Physical Characteristics of Groundwater

Major Cation Characteristics

Calcium

Calcium is said to be a significant determinant of total hardness in water, and it acts as a pH stabiliser. Almost all the calcium compounds are soluble in water. Thus, hard water usually contains high calcium content along with other mineral components. Usually, the water reaches into the ground through limestone that carries a high amount of calcium in it. The permissible limit of calcium in groundwater is 75 mg/ l to 200 mg/l. If it exceeds or lower than this limit that leads to health hazards like cardio-vascular diseases, growth retardation and also creates some health problems. The calcium is varying from 11 to 450mg/l in the basin with a mean concentration of 77mg/l. About 73 per cent of the samples are in the desirable ranges, 15 per cent are in the permissible ranges, and the rest of the samples are in the not permissible range. The central and eastern portions of the basin possess a high value of calcium concentration.

Magnesium

Magnesium is another crucial determinant that plays an important role in water hardness. It is present in most of the minerals such as dolomite, magnesite, etc. Hence, the primary source of magnesium in the groundwater is through the rocks that contain these minerals. The desirable limit of magnesium in groundwater is 30 mg/l. The deficiency of magnesium leads to neurological and neuromuscular functioning, which results in anorexia, muscular weakness and tiredness. Magnesium salts are used as cathartics and anti-convulsant (medicinal use). The presence of magnesium in water is generally beneficial. For the protection of human or aquatic health, no limits on magnesium have been established. The concentration of magnesium is varying from 2 to 250mg/l. The average concentration of magnesium is 77 mg/l. Only the 8 per cent of the samples come under the desirable limit, 77 per cent is under the permissible limit, and 15 per cent is not under the permissible limit.

Sodium

Sodium is an alkaline which contains sodium hydroxide and hydrogen gas. It is a strongly water-soluble element. Water with an excess amount of sodium may cause cardio-vascular renal diseases (Russell and Edward, 1970). The reactions of sodium ions differ in adults and infants because of the immaturity of kidneys. This effect on infants creates gastrointestinal infections that lead to fluid loss, leading to dehydration and raised sodium levels in the plasma (hypernatremia).The value of sodium ranging between 9 and 1650 mg/l with a mean of 234 mg/l. About 50 per cent of the samples exceed the WHO standard and not potable for drinking. Sodium is found to be high along the eastern part of the basin.

Potassium

Potassium is an element which is commonly found in soils and rocks. In water, it has no smell or colour but may give water a salty taste. It is one of the essential nutrients in drinking water which is essential for heart functioning, muscle contraction and water balance in the human body. The potassium concentration exceeds the limit leads to

hyperkalaemia and cardiovascular problems. Potassium is an essential element for human beings. The value of potassium in the basin is ranging from 5 to 315 mg/l, with an average concentration of 48 mg/l. Most of the samples are present under the desirable ranges of magnesium.

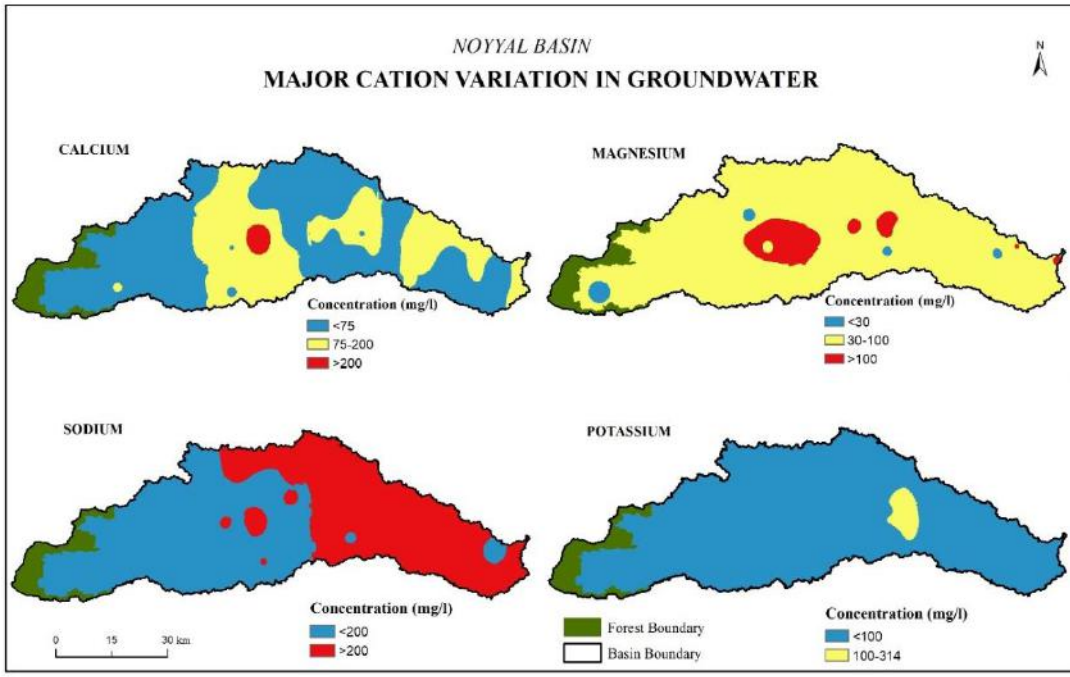

Fig. 2. Major Cation Variation in Groundwater

Major Anion Characteristics

Chloride

Chloride is the most important anion, which is essential for the electrolyte balance of body fluids. More than a health concern, chloride determines the taste of water. However, a high concentration of chloride leads to palatability, affects digestion and adverse to persons having heart and kidney diseases. Sodium chloride ingestion is the principal causative agent in arterial hypertension (Meneely, 1961). The chloride concentration in the basin ranging between 158 and 9000 mg/l, with a mean value of 1018 mg/l. About 48 per cent of the samples comes under the desirable limit, 31 per cent are under permissible, and the remaining 21 per cent are in the not permissible conditions for drinking.

Nitrate

The primary natural source of nitrates in groundwater is mainly from the igneous rocks, and it is very minimal. The desirable limit of nitrates in drinking water is 45, and if it exceeds the desirable limits cause adverse health effects. It also affects the aquatic fauna in surface water. Nitrate enters the human body by the use of groundwater and it causes

several health hazards like gastric cancer, goitre, birth malformations, hypertension etc., when present in high concentration in drinking water (Majumdar et al., 2000). Methemoglobinemia and carcinogenic risks were caused due to the excess amount of nitrogen in drinking water. The value of nitrate in the basin varying from 1.5 to 66 mg/l with an average of 16 mg/l. About 69 per cent of the samples are under the desirable limit, and the remaining samples are in the permissible limit for drinking.

Sulphate

Sulphates are mainly derived from the sedimentary rocks. The permissible limit of sulphate is 200 to 400 mg/l. It causes gastrointestinal irritation when Mg or Na is present, and also it affects the taste of the drinking water. Higher concentrations of sulphate in drinking water cause diarrhoea (Heizer et al., 1997). The concentration of sulphates in the study area varies from 2.5 to 97 mg/l, and its average concentration is 37 mg/l. All the samples sulphate concentration is under the desirable limit.

Bicarbonate

The primary source of carbonates and bicarbonates in groundwater is from the dissolved carbon-di-oxide in the rain. There is no proper guideline given for bi-carbonate concentration in drinking water. The higher concentration of bicarbonate in water leads to cardiovascular and non-cardiovascular risks (Raphael et al., 2016). The presence of carbonate in water leads to Kidney stone (Senguptha, 2013). The value of bicarbonates ranges from 163 to 430 mg/l, and it's mean is 250 mg/l.

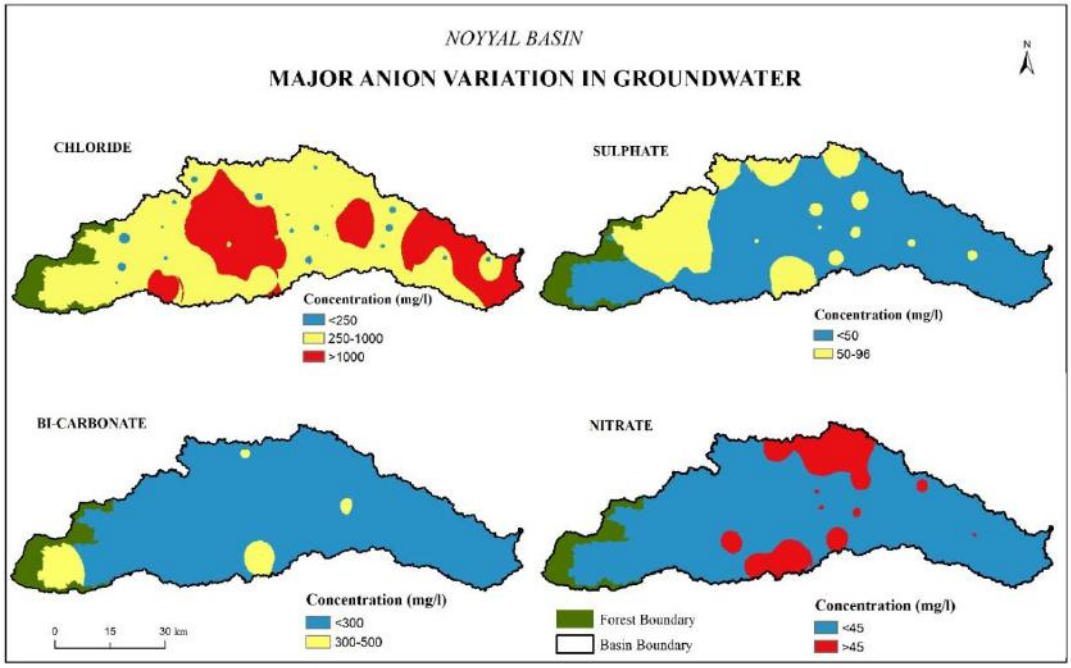

Fig. 4. Major Cation Variation in Groundwater

Conclusion

This paper intends to analyse the geochemical parameters of the groundwater for the consumption of water in the Noyyal River basin. Here an investigation has been conducted, and the physical and chemical parameters were analysed in the laboratory. The study reveals that water samples are highly alkaline and hard in nature. The samples show very high conductance and TDS values, and hence most of the samples are in saline condition. The values of sulphate, bicarbonate and nitrate in the groundwater are under the desirable ranges. The result shows that the calcium, magnesium, sodium and chloride in the samples are not meeting the permissible limit. The spatial distribution of TDS, calcium and chloride follow a similar pattern with three extremes in the central, eastern and easternmost portions of the basin. The sodium concentration is extremely high in the eastern part of the basin.

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FARMERS' PERSPECTIVES ON FOOD CROPS PRODUCTIVITY IN SOUTHERN RAJASTHAN

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Abstract

Agricultural production systems are expected to produce food for a global population that is expected to reach 9.1 billion by 2050 and over 10 billion by the end of the century (UNFPA 2011). Currently, the global production of food has achieved remarkable significance while the rapid growth in population and consequently the high demand for food has led to a gradual increase in food prices. This paper examines the adoption data of multiple levels such as the type of soil, consumption of fertilizers, the size of land holding, use of high-yielding varieties, irrigation facilities, etc. A factor-wise comparative study of productivity and area was done and observation data were collected from 280 farmers related to different communities and 14 villages of southern Rajasthan. Chi-square and standard division technique were used for data analysis. It was found that size of holding, type of soil, caste category and modern mechanization have great impact on food productivity in the study region..

Keywords: Southern Rajasthan, Food productivity, Farmers

Introduction

Farmer's attitudes and behaviours are influenced by a range of economic, internal and social factors. These factors effect all the business decisions of farmers, including what and how to produce (farm management practices). However, there are additional considerations which are related specifically to farmers. Farmers are different from other population groups in that their attitudes and behaviours influence many components of agricultural systems, including crops and input supplies. In addition, farmers' decision-making processes are more complex than those in other sectors because climate is the primary determinant of agricultural productivity and agricultural activities depend on and have a huge impact on climate. The research into firm decision-making has traditionally focused on individual farmers. Inevitably, family members of different ages / genders and educational background will be influenced by different factors and make different decisions, so it is important to consider this aspect of the decision-making process when considering how farmer's behaviours may be influenced.

Study Area

The region lies in the southern part of the State of Rajasthan. The study area comprises seven southern districts of the State, namely: Banswara, Bhilwara, Chittorgarh, Dungarpur, Rajsamand, Pratapgarh and Udaipur, with 54 tehsils according to 2011 census. Geographically, the region is located between 23°1'10" to 26°1' 15" North latitude and 73°1' 10" to 75° 43' 30" East longitude occupying an area of 47,397 square kilometres. It extends nearly 210 kilometres in North–South and240 kilometres in the East–West direction. The region is bounded by Bundi and Kota Districts in the East, by Mandsor, Ratlam and Jabua Districts of Madhya Pradesh in the south-east and by Banaskanta, Sabarkanta and Panchmahal districts of Gujarat in the South.

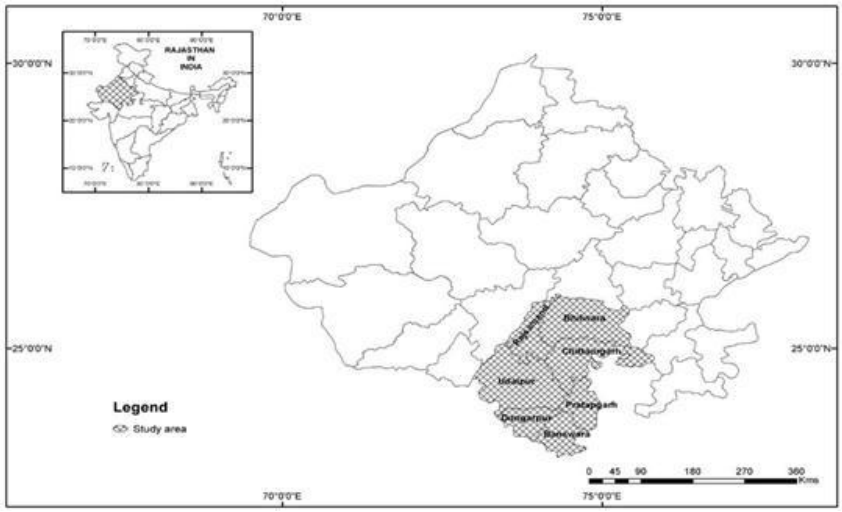

Fig. 1. The Southern Districts of the State of Rajasthan

Its Pali and Sirohi Districts lie in its west and the whole of the northern boundary of the region is common with the Ajmer District of Rajasthan; over a few kilometres, Tonk District also touches its north-eastern boundaries. However, over the recent decades, farm size is decreasing in southern Rajasthan due to the growth of population. The objectives of the study are to understand the food productivity of different sampling farmers, analyse the farmer's perception towards food productivity and study the problems of farmers.

Database and Methodology

Primary data regarding farm-level study have been collected from the selected farmers by interviewing them personally.

(i) Selection of Sample Villages

A sample survey of farmers was undertaken in all districts of the Southern Rajasthan such as Banswara, Bhilwara, Chittorgarh, Dungarpur, Rajsamand, Pratapgarh

and Udaipur. Broadly, a stratified random sampling process was followed. A major consideration for the selection of the districts was sampling of different agro climatic regions, and as indicated, these districts belong to tribal, non-tribal and semi-tribal areas of the study region. In the second step of sampling, two tehsils which have maximum and minimum food crops productivity were selected. After selecting the tehsils, one village was selected from each tehsil. The villages were selected on the basis of population size, social category such as Scheduled Tribe, Scheduled Caste, Other Backward Class and General Population (More than 50% of population), accessible and inaccessible villages from tehsil headquarters, more irrigated land and less irrigated land in village level of the tehsil. In this way, total 14 villages and 280 farmers were covered across 7 districts and 14 tehsils.

(ii) Criteria for Selection of Household

Twenty households from each sample village of the fourteen tehsils in all the districts have been taken up for study. Two hundred eighty households have been selected on the basis of their farm size, literacy rate, economic conditions and use–non-use of modern agricultural implements through stratified random sampling. Primary information about socio-economic status of farmers, agriculture land-use pattern, area and production of crops, use of modern agricultural machinery and fertilizers, area and production of crops and farmer's perception towards use of technology and productivity-effecting factors, etc. Much information was collected through personal interview and schedule method at household level.

Social Education and Agriculture Population of Sampling Farmers

Population and its composition are important contributory factors in agriculture and agriculture is basically a labour intensive activity, and much of the labour requirements are met from the family itself. The details related to this factor in tribal and non-tribal and semi-tribal villages are presented in Table 6.2. The result of study indicated that a village having a total population of 1358 persons had 280 farmers. But Tribal villages were more populated in comparison to other villages. Agriculture population of sampling farmers is 50.37 per cent of the total population, but category wise agricultural population is more in tribal villages in comparison to other category. It's indicated that fifty per cent population of the total selected families of farmers has been engaged in agricultural work. Age-group wise study indicates that the number of adults was more than that of children implying relatively more availability of work force for agriculture in the study area. The study of educational level of farmer's family members shows that better education enables better comprehension of farming technologies and their possible adoption in farm enterprises. The awareness and knowledge level of the farmers is best reflected through their educational level. The distribution of sample farmers according to the education of heads of the farmer's families is presented in table 1. The results indicated that 36.82 per cent of farmer families were illiterate, 35.71 per cent of farmer families had education up to primary level and 21.21 per cent of farmer families had education up to secondary level. It was observed that only

6.26 per cent of total sample farmers in the study region were educated up to senior secondary and above . The per centage of population that participated full time in agricultural work was 41.97 per cent in one agriculture year; 30.56 per cent population was not engaged in agriculture activities; and 27.47 per cent population engaged in seasonal activities.

Table 1. Village Wise Category of Population, Age, Education and Engaged in Agriculture work (in Per cent)

Village	Population of Sampling Farmers		Age Group			Education Level				Population participated in Agricultural Work		
	Total Population	Agriculture Population	<18	18-45	>45	Illiterate	Primary Education	Secondary Education	Above Secondary Education	Full Time	Seasonal Time	None
Non-scheduled Tribal village	290	44.95	31.18	35.54	33.28	28.92	35.19	27.70	8.19	39.89	28.75	31.36
Semi tribal village	105	45.06	30.86	40.12	29.02	25.93	47.52	16.67	9.88	21.60	25.31	53.09
Scheduled Tribal village	360	56.75	37.14	33.60	29.26	46.94	33.12	16.40	3.54	49.19	26.85	23.96
Total (of the total respondents)	755	50.37	33.87	35.20	30.93	36.82	35.71	21.21	6.26	41.97	27.47	30.56

***Source**: On the Case of Primary Survey – 2015*

Factor-wise Analysis and Discussion

The factors like types of soil, use of fertilizers and size of land holding play an important role in controlling greatly the food productivity in a particular region. The different physical conditions are indeed responsible for variations in regional patterns of agricultural phenomena: However, the differential degree of combination of institutional, operational infrastructural factors influence food crops patterns and level of food productivity. These factors must be considered useful and their discussion is un-avoidable to comprehend the varying levels of agricultural developments from place to place at a point of time. There is a plethora of factors which have a bearing upon the production and productivity of the food crops. First of all the sample data of 280 farmers are classified and tabulated so as to identify factors responsible for causing variations. The important factors among them are the nature of soil, consumption of fertilizers, the size of land holding, use of high-yielding varieties, irrigation facilities, etc. The factor-wise comparative position of production, area and productivity is shown in the following sections.

Types of Soil

Soil is an important determinant of production and yield of food crops as well as other crops. As many as 280 farmers were surveyed and from the survey, it was found that per hectare productivity was the highest in the farms having black soil. Area production and yield soil wise are shown in Table 2. It is clear from the table that red, black, medium black and yellow soils have the productivity more than the average of the total sample farms. Hilly and sandy, Brown and loamy soil's productivity were found to be below average. Hence, it can be concluded that the areas having black, medium black and yellow soil have more potential for producing food crops.

Use of Fertilizers

The proper use of fertilizers enhances the productivity of the land. The information gathered from 280 farmers clearly reflects the fact that less or more than the optimum level of fertilizer decreases the productivity, the relation between fertilizers and productivity is presented in Table 3. It is clear from the table that the farmers using 300–400 kg. DAP and Urea per hectare were having the highest productivity of food crops.. But the productivity declined in the farmers using less than 100 kilograms of DAP and Urea or using more than 400 kilograms of DAP and Urea. Thus, it is clear that 300–400 kg. hectare use of DAP and Urea is ideal for food crops.

Size of Land Holding

One of the important institutional factors determining the productivity of food crops is the size of land holding. The economy of seeds, availability of resources, economic availability of agricultural activity and effective management for large farm size gives better results than that of the small size of farms. It is clear from Table 4 that large farms were getting more yields in comparison to the medium and small farms.

Table 2. Soil Type and Food Productivity (on the Basis of Sampling Farmers)

Soil Type	Total Food Crops Area (in Hectare)	Total Production (in Metric Tons)	Productivity (Tons Per Hectare)
Red	98.5	192.1	1.95
Black	48.75	131.7	2.70
Medium Black	133.5	314.4	2.36
Hilly and Sandy	153.25	159	1.037
Brown and Lomy	74.25	101.9	1.37
Yellow	79	172.3	2.18
Total	587.25	1071.4	1.85

***Source**: Primary Survey*

Table 3. Use of Fertilizers and Food Crops Productivity (on the Basis of Sampling Farmers)

Fertilizer Consumption (Per Hectare Kg.)	Total Area (in Hectare)	Total Production (in Metric Tons)	Productivity (Tons Per Hectare)
0–100	139.25	146.1	1.04
100–200	122.25	215.7	1.76
200–300	187	337	1.80
300–400	51.25	156	3.04
>400	87.5	216.6	2.47
Total	587.25	1071.4	1.85

***Source**: Primary Survey Based*

Caste Category Wise Productivity

Efforts are made to investigate the impact of caste on the average productivity. The results are presented in Table 5. It is evident from the table that social category of farmers is an important factor which affects the production and productivity in the study region. The

average productivity of farmers run by OBC and General caste farmers was found to be higher than that of farmers run by Scheduled Tribe and Schedule Cast farmers.

Use of Pesticides and Improved Seeds

Efforts are made to investigate the impact of pesticides on the productivity. Approximately 32 per cent respondents have used the pesticides occasionally, while 30.36 per cent farmers used pesticide and 37.5 per cent farmers never used pesticides. Regarding the use of improved seeds, majority of the farmers perceived that they used, Rajasthan 911, *Sonalika and Lokwan* improved seeds of wheat; and *Mahi Kenchen, Dhevel, Cp, Kiran, Ganga 2, Gangall, Decan 103, Aravellimeka* Improved seeds of maize; CSV13, CSV10, CSH1, improved seeds of *Jowar Krishena*; T9 improved seed of used pulses etc. on their land for better production. In this type, 11.07 per cent farmers used both seed types. Above 38 per cent farmers used normal seeds. They think that normal seeds are good for food and are of the best quality.

Information of Agricultural Food Grains

A thorough study for collecting information about agricultural food grains - was conducted on 120 non-tribal respondents, 120 tribal respondents and 40 semi-tribal respondents to find out the main reasons behind the selection of food crops in a particular season by them. Various facts were gathered from these respondents to make this study authentic. This study has been divided into four categories on the basis of the facts gathered from the respondents. These four categories are as follows: 1. Main reasons for selecting food crops in a particular season by farmers, 2. Use of new technology, 3. Lack of knowledge, 4. Effective informative source and access to innovation.

Main Reasons for Selecting Food Crops in Season by Farmers

Among non-tribal farmers, 24.78% considered availability of seeds as the main factor in the selection process of crops; 19.74% non-tribal farmers accepted economic profit of crops as a crucial element in making decision about the selection of crops while 24.76% of them held supply for family need as a responsible agent behind it. According to survey, 20.01% tribal farmers held market facilities while a 14.93% held availability of agricultural land as the main reason behind the selection of food crops in season. The 42.81% semi-tribal famers observed market facilities as the decisive factor in this process of selection.

Use of New Technology

Among non-tribal farmers, 40.05% use agricultural farmhouse, 31.51% of them use thresher while 23.54% opt for irrigation system in the form of new technology. When the same study was made on tribal farmers, the use of tractor became the first choice for 40.31%, 13.04% used thresher and agricultural system was used by only 15.46% tribal farmers. Semi-tribal farmers' responses from survey were as follows: 50.29% of them used thresher, 58.17% used tractor while 52.91% accepted to have used sprinkle irrigation

system for the production of food grains. A very surprising fact cropped up through this survey that new technology is used mostly in semi-tribal area. *Thus, tribal farmers are laggards or late adopters.*

Table 4. On the Basis of Size of Land Holding

Farm Level	Farm Size	Total Food Crops Area (In Hectare)	Total Food Production (in Metric Tons)	Productivity (Tons per Hectare)
Very Small	<0.5	185.25	267	1.44
Small	0.5-1.0	243	443.0	1.82
Semi-Medium	1.0-2.0	101.5	226.2	2.22
Medium	2.0-5.0	32	72.4	2.26
Large	>5	25.5	62.8	2.46
Total		587.25	1071.4	1.85

Source: Primary Survey

Table 5. Category Wise Food Productivity

Farmers	Total Food Crops Area (in Hectare)	Total Food Production (Metric Tons)	Productivity (Tons per Hectare)
General	219.25	491.5	2.24
OBC	170.75	338.2	1.98
ST	73.75	73.70	0.99
SC	123.5	168.0	1.36
Total	587.25	1071.4	1.85

Source*: Primary Survey Based*

Lack of Knowledge

Among non-tribal farmers, 55.27% considered lack of awareness and technical knowledge as a hurdle in the production of food grains; 25.92% accepted that their weak economic condition prevented them from getting better result in food production while small size of holding proved a dissuading element for 41.36. The study on the tribal farmers presented different things. Problem of electricity served as a major cause behind the low production of food grain for 28.65% tribal farmers while 10.17% of them (tribal farmer) agreed that small size of holding was a crucial aspect behind the slow process of food-grain production. Semi-tribal farmers also faced similar problems with different reasons behind them as lack of awareness and knowledge put those 44.85% at risk in their agricultural like while 35.36% of them faced the problem of weak economic conditions. The study of three categories of farmers mentioned above shows that lack of technical knowledge and awareness is the main element which obstructs the development of agriculture.

Effective Information Source and Access to Innovation

In this category, 60.05 non-tribal farmers emphasized the need of farming training and seminar while 56% farmers of this category stressed the importance of agricultural knowledge through experts (supervisor). When the study was conducted on tribal farmers regarding the same topic, 59.04% of them accepted the useful role of radio and television in the agricultural development; 46.32% of them (farmers) consider that agricultural supervisor

can play a vital role in the advancement of the agriculture. 57.41% semi-tribal (farmers) also accepted the importance of agricultural supervisor in the field of agriculture and 40.46% admitted that only rich farmers can benefit from innovation and take risk. Among semi-tribal farmers, 47.44% approved the role of neighbour farmers also in agricultural development. Survey shows that innovations and effective information source can be effective steps for the advancement of agriculture.

Table 6. Information of Agriculture Food Grain

S. No.		Variables	Non-Tribal Farmers		Tribal Farmers		Semi-Tribal	
			$\bar{x}$	C.V.	$\bar{x}$	C.V.	$\bar{x}$	C.V.
1. Main reason of food crops selected in the season for growing	1	Availability of seeds	12.71	24.78	9.17	15.48	10.71	28.29
	2	Economic profit of crops	12.88	19.74	9.33	13.39	11.07	25.92
	3	Storage facilities	8.5	30.58	7	11.57	8	38.25
	4	Market facilities (Mandi)	9.33	25.29	7.33	21.01	9.04	42.81
	5	Available of Agriculture land	11.17	9.22	7.5	14.93	3.05	34.75
	6	Supply for family need	11.67	24.76	6.5	16.92	11.00	36.91
2. Use of new technology	1	Thresher	15.38	31.51	11.5	13.04	12.07	50.29
	2	Tractor	15.67	27.95	9.33	40.31	10.09	58.17
	3	Sprinkle Irrigation system	6.33	23.54	0.30	31.30	3.4	52.91
	4	Use of Agriculture farmhouse	4.17	40.05	0.16	33.86	3.18	64.15
	5	Use of solar energy	2.33	20.17	0.83	19.66	0.40	35
	6	New Agriculture system	3.83	27.94	0.50	15.46	6.07	50.57
3. Use of new technology	1	Lack of technical and awareness knowledge	5.5	55.27	11.83	22.57	9.10	44.83
	2	Weak economic condition	5.17	25.92	11.67	12.77	10.01	35.36
	3	Lack of Farming Knowledge	6.33	33.17	10.17	11.50	9.7	28.45
	4	Small size of holding	3.3	46.36	10.17	19.96	7.7	21.69
	5	Problem of Electricity	12	10.75	7.33	28.65	6.30	33.65
	6	Problem of water	3.83	9.66	6.12	11.27	5.12	31.25
	7	Others	11.17	11.99	6	11.67	4	46.75
4. Effective Informative source and access to innovation	1	From training and seminar	3.83	60.05	0.00	0.00	6.4	16.56
	2	From Agriculture University	3	56	0.00	0.00	10.4	28.27
	3	From Agriculture demonstration and village camps	9.00	14.44	4.67	31.90	9.67	17.27
	4	From Radio / T.V.	3.33	22.22	0.83	59.04	6.67	28.03
	5	From Agriculture supervisor	12	23.58	3.67	46.32	12.07	57.41
	6	Kisan Call Centre	2.5	66.4	0.83	2.41	0.60	21.66
	7	Rich Farmer Family	4	41.75	8.83	14.16	6.03	40.46
	8	Neighbour	4.5	38.67	12.5	12	6.05	47.44

*Non-Tribal Respondents = 120, Tribal Respondents = 120 Semi-Tribal Respondents = 40 (**Source**: Calculated using SPSS)*

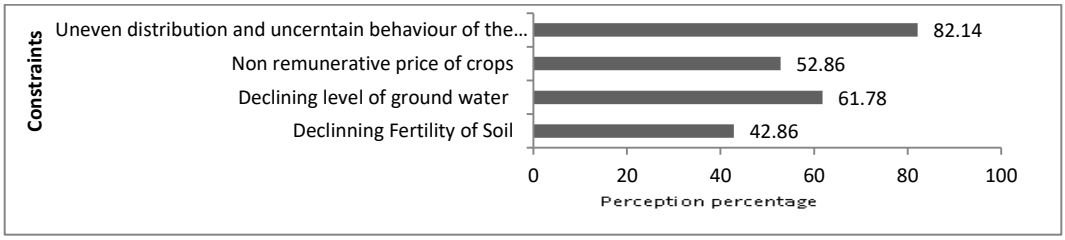

Fig. 2. Constraints with Effect on Food Productivity Level (Based on 280 'Yes' or 'No' Responses)

Awareness and Perceptions of Farmers

In a study of this region, farmers identify the main influences on their decision-making. The farmers accepted that the following factors in agriculture help to increase the productivity level and thus farmers give preference to their own choice for these: soil type, chemical fertilizer, high-yielding varieties, irrigation facilities, modern mechanization, agriculture labourer, etc. It has been intensively focused in field survey. Chi-square tests were applied to fourteen factors, as shown in the table below, against the attitude score of the individual respondents. Each of the respondents was given a score based on his attitude towards food crops' productivity. "0" was ('no' answered) assigned for negative (Table 7). Attitude and "1" ('Yes' Answered) for positive attitude. In this way, chi-square tests were applied to individual factors against attitude score. The tests applied on the data generated from this study. Results of the test indicated that there were significant relationships (P<.0.05) between farmer's perception towards soil type, chemical fertilizer, High-yielding varieties, Irrigation facilities, modern mechanization, New information, weather knowledge in time for growing crops, uncertainty and irregular rainfall, awareness of farmers, changing prices and subsidy price of food crops, decrease in level of soil fertility etc. – the factors that affect level of the food crop productivity. It means that these farmer's attitude or perception towards food crops productivity on the other hand, (two) variables i.e. effect of agriculture labour, education level of farmers, have no significant relationship (P>0.05) with attitude score of the farmers. Thus, out of 14 variables, twelve shows significant variance for the attitude and perception towards food crops productivity and only two variables remain insignificant.

Table 7. Awareness and Perception of Farmers

Sl. No.	Variables	No. of Respondents	Chi-square (X^2)	p-Value	Hypothesis Result
1.	Effect of soil type on food production	280	20.23	0.333	Accept
2.	Effect of chemical Fertilizer on food production	280	14.58	0.412	Accept
3.	Effect of High-Yielding varieties	280	18.21	0.312	Accept
4.	Effect of irrigation facilities and electricity availability	280	21.43	0.257	Accept
5.	Effect of tractor, harvester, thresher etc. mechanization	280	17.65	0.566	Accept
6.	Effect of Agriculture labours	280	6.85	0.043	Reject
7.	Effect of New Information related Agriculture	280	19.12	0.150	Accept
8.	Effect of weather knowledge on time	280	19.75	0.271	Accept
9.	Effect of Uncertainty and irregularity in rainfall	280	22.32	0.403	Accept
10.	Effect of Awareness of farmers	280	14.98	0.980	Accept
11.	Effect of Education level of farmers	280	18.21	0.023	Reject
12.	Effect of changing price and subsidy price of food crops	280	23.04	0.360	Accept
13	Effect of continuous downfall in level of ground water	280	14.43	0.012	Reject
14.	Effect of decreased level of soil fertility	280	19.38	0.304	Accept

***Source**: Calculated using SPSS*

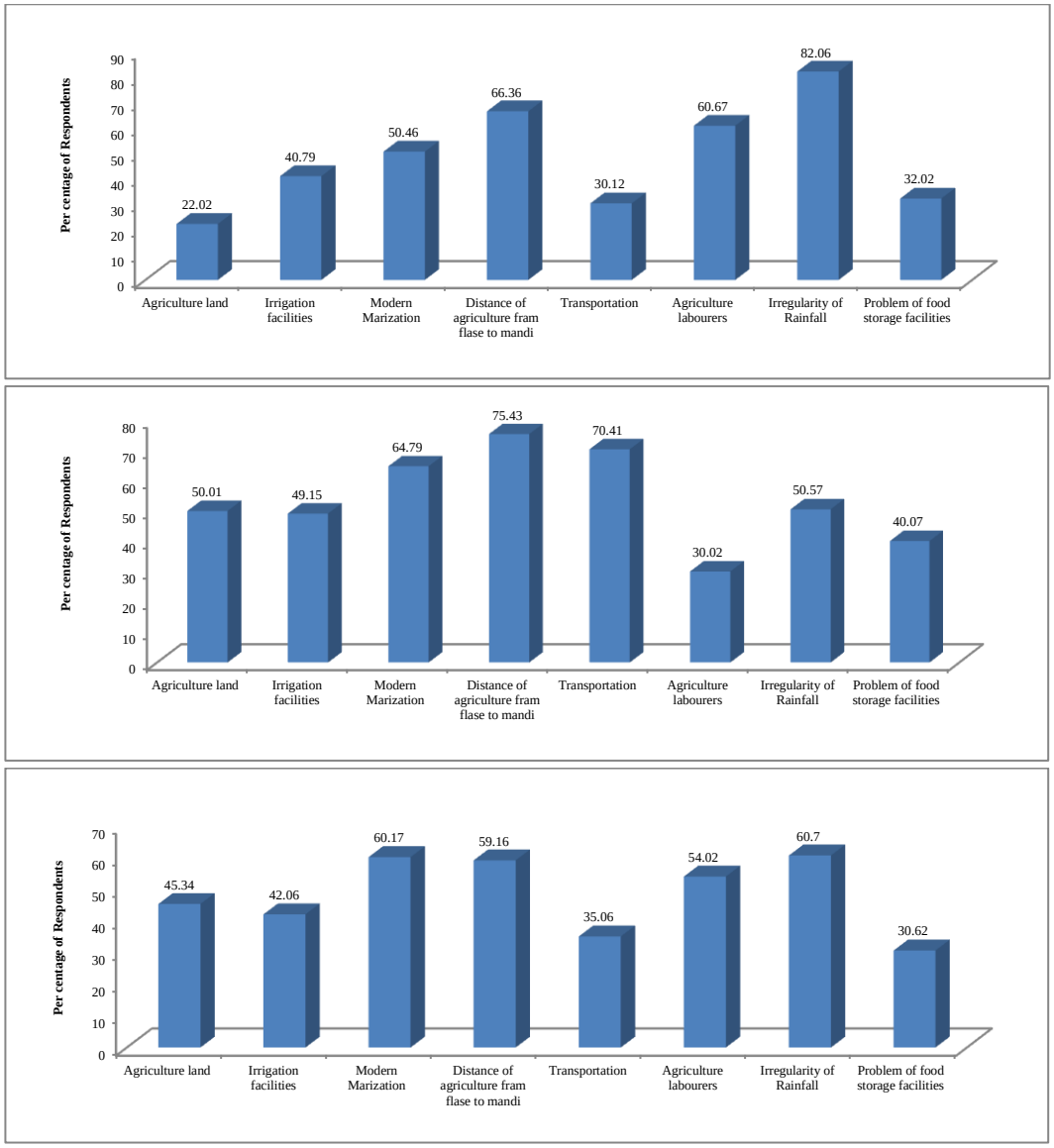

Fig. 3. (a) Problem of Food Productivity in Non-Tribal Farmers during Field Survey, 2014 (b) Problem of Food Productivity in Tribal Farmers during Field Survey (c) Problem of food productivity in semi-tribal farmers during field Survey

Conclusions

After a detailed survey of the sample villages of the study area, it was observed that there were wide disparities in food crops' productivity and development of effecting factors in the study area. The fourteen study villages are situated in different agro-climatic and socio-economic conditions in southern Rajasthan. The survey brings out wide disparities in food crops productivity across these sample villages. Pandoli (Chittorgarh), Sareri (Hurda), Sakroda (Udaipur), Sakroda (Amet) Karunda (Chotisadri) villages have witnessed very high

level of food crops' productivity. The main reasons for very high level of agricultural development are developed infrastructure, well-developed irrigational facilities, fertile soil, high-yielding variety of seeds and adoption of the advance farm technology by farmers. Rohaniya (Peeplekhut), Garatesher (Simalwara), Charkani (Kushalgarh), Navaniya (Vallabhangar) villages of tribal, and semi-tribal area have low level of food productivity.

- The presence of rocky surface, deep inadequate acquifers of sub-soil water, low-extent irrigation were responsible for low level of agricultural development. In the southern Rajasthan to minimize regional disparity and achieve higher and sustainable level of food crop productivity, the following suggestions are proposed:

- For high growth rate, farm inputs like seeds, fertilizers and irrigational facilities play an important role. There is a need for equitable and efficient use of inputs, so that regional disparities in its use can be minimized.

- Small and scattered holding of landuse area is one of the reasons of low food crop productivity. This is an obstacle in the way of modern agriculture in which machines, improved equipments and techniques are used. These problems should be minimized through consolidation of land holdings. This problem needs to be addressed on priority basis by the respective governments. Unless small farmers are helped to improve the productivity and profitability of their farms, the agriculture in southern Rajasthan will not be developed in its true sense. This can be possible by optimum use of available land, water, credit facilities and labour resources.

- The use of improved agricultural implements and machines such as plough, tractor, trolley, harvester, thresher, water pump, sprinkle etc. are important to modernize agriculture. These machines are being used in non-tribal tehsils, but in tribal area the mechanization level is comparatively low. There is urgent need to mechanize the agricultural operations so that wastage of labour force can be avoided and farming is made convenient and efficient.

- The governments must develop various infrastructural facilities in rural areas - e.g. electrification, provision of irrigation facilities, construction of metalled roads to connect villages to the markets. There is a need of spreading these facilities to small farms, in general and to the farmers of remote areas in particular.

- Agricultural marketing is still continued to be in a bad shape in rural areas. In the absence of sound marketing facilities, the farmers have to depend upon local traders. The government should establish regulated markets in large numbers.

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ASSESSMENT OF DRINKING WATER QUALITY, RELATED HEALTH IMPACTS AND ACCESSIBILITY TO PUBLIC HEALTH CURATIVE SERVICES AMONG SLUM DWELLERS IN DEHRADUN CITY OF UTTARAKHAND, INDIA

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Abstract

The child population in slums of Dehradun city is at significant risk of water-borne diseases. This study aimed to assess the bacteriological quality of drinking water during pre and post-monsoon months for five different slum locations of Dehradun city and water-related diseases affecting the child population of 0-5 years of age during the post-monsoon month. Also, perception study of slum dwellers has been carried out regarding access to public health care services and various barriers to it. In total 30 drinking water samples from point of use were collected from five slums during the months of May and August and bacteriological analysis was done using standard methods. Health-related information based on the prevalence rate of water-borne diseases was gathered through pre-designed survey questionnaires. Results showed that all water samples were found highly contaminated during the post-monsoon month with mean values of Total Coliform at 1129.52±970.28 count/100 mL and E.coli at 22.37±11.74 count/100 mL respectively. The point prevalence rate of Diarrhea among all children was found to be highest i.e. 45 per cent out of five diseases. In addition, total cases of child population affected by water-related diseases were found negatively correlated with various social and environmental factors. Public health care services for medical treatment was only preferred by 26 per cent of slum dwellers due to the existence of various barriers.

Keywords: Bacteriological Analysis; Public Health Service; Waterborne Diseases; Socio-Economic Factors; Child Health

Introduction

Water is a necessary element for life. The provision of safe drinkable water is a precondition for a healthy living and thus provides immunity to fight against poverty, hunger and deaths. The Millennium Development Goals pledged to reduce by half the proportion of people without access to safe drinking water (Wagstaff and Claeson 2004). Out of total water availability on earth, only 3 per cent is fresh water and out of which only 0.01 per cent of the total freshwater has been offered for human use (Hinrichsen and Tacio 2002). Even this little proportion of freshwater is under immense pressure due to various factors such as

population growth, urbanization and huge consumption of water in trade and agriculture sector. As per the UNO report, the human population on the planet is increasing exponentially while the availability of fresh water is declining enormously. Several countries of the Middle East, Africa and South Asia will have serious threats of water shortage within the next 20 years.

In developing countries, the problem is further aggravated due to the lack of proper management, unavailability of professionals and financial constraint (Ahmed et al. 2015). The quality of drinking water is directly associated with human health and indicates the effectiveness of environmental protection measures (Chung et al. 2009). According to Kovacs, integration of various environmental factors contributes to the pollution of surface water bodies (Kovacs et al. 1986). Not only the discharge of industrial effluents and accidental spills, issues such as deforestation, urbanization, intensification in agriculture and non-point sources are also aggravating this problem.

More than a billion people do not have access to safe drinking water and well over 2 billion people live without adequate sanitation. The number of persons in urban areas of the developing countries with no access to safe drinking water increases sharply due to rapid urbanization mainly in peri-urban and slum areas since the last decade (WHO 2010). At any given time, more than half of the developing world's child population is suffering from one or more of the main diseases associated with unsafe water and poor sanitation (WHO 2019).

Dehradun city, the largest and the capital city of the western Himalayan state of Uttarakhand is among such which has grown four-fold in the last decades. With the rapid urbanization, however, these cities are inviting many social and environmental problems due to the increasing burden of the rising population. The major living sites for the urban poor in Dehradun city are slums which are mainly found along the Rispana and Bindal River. Out of the total city population, almost 25 per cent of the population lives in slum areas. There are 129 notified slums as per the 2011 Census (Census of India 2011). Due to pathogen prone surroundings, with cramped conditions in shacks and with limited access to civic services such as safe drinking water supply, sanitary toilets and waste disposal facilities, these urban poor belongs to the major sufferer group from the urban society (Hardoy and Satterthwaite 1991). For children, the chances of survival dwindle in the absence of safe drinking water. Every day almost 6,000 children die due to water-borne diseases. Young children are the first to get sick and die from waterborne related illnesses-including diarrhoeal diseases (UNICEF 2014).

The increasing pollution of drinking water sources in Dehradun and the consequent effects on human health issues is of great concern. This review aims at highlighting the problem of water quality in five slums of Dehradun city with special emphasis on Total Coliform and E.coli and related health impacts on the child population in the form of various water-related diseases. The water provided by the Uttarakhand Jal Sansthan through the pipelines is the main source of drinking water, therefore, we concentrate only on surface

water. Furthermore, based on the age classification of children of the slum dwellers, various links have been established between the total number of children affected by the water-borne disease and various social and environmental-related factors prevailing out there. Also, a study has been carried out based on the perception of slum dwellers regarding accessibility to public health services and various barriers to it.

Database and Methodology

Site Selection

Five settlements of urban poor representing slums, as mentioned in (Table 1), were chosen under this study based on three criteria: near to the City Centre, along with Untenable Site and near to the Fringe Area of the city (Figure 1). Bhagat Singh Colony and New Khurbura are located close to the city centre and among them, Khurbura is the oldest mohalla of Dehradun city. Rajeev Nagar and Deep Nagar are situated along the Rispana River thus acts as an untenable slum site. Indira Nagar Colony slum is situated close to the fringe area of the city. A total of 150 households was randomly selected for the pilot study and out of which the sample households in each slum have been selected in the same proportion as out of their actual households.

Table 1. Details on Settlement Size and Sample Households

Settlement	Total Households	Sample Households
Deep Nagar	2,123	39
Rajeev Nagar	2,839	52
Indira Nagar Colony (INC)	1,230	23
New Khurbura	1,297	24
Bhagat Singh Colony (BSC)	670	12

Data Collection and Indicators Used

Firstly during the month of May (pre-monsoon) and August (post-monsoon) some bacteriological analysis of the drinking water was performed for which three samples from each slum for a particular month was collected in sterilized bottles and tested in the government-certified laboratory. A total of 30 drinking water samples were collected randomly from point of use. All the sampling procedures were carried out according to the guidelines prescribed by Standard Methods for Examination of Water and Wastewater (APHA 2017).

Secondly, during the month of August (post-monsoon), a survey has been carried out for 150 households. Purposive selection of houses was performed with one consideration i.e. there must be at least one child per household belonging to the age group of 0 to 5 years. The questions were organized and divided into so as to get information on some broad perspectives such as socio-economic, infrastructure, the prevalence of water-borne diseases among children and accessibility to public health care services. Data obtained through the survey were analysed using Microsoft Excel for descriptive statistical

analysis and drinking water samples laboratory results were analysed using the Most Probable Number (MPN) Technique.

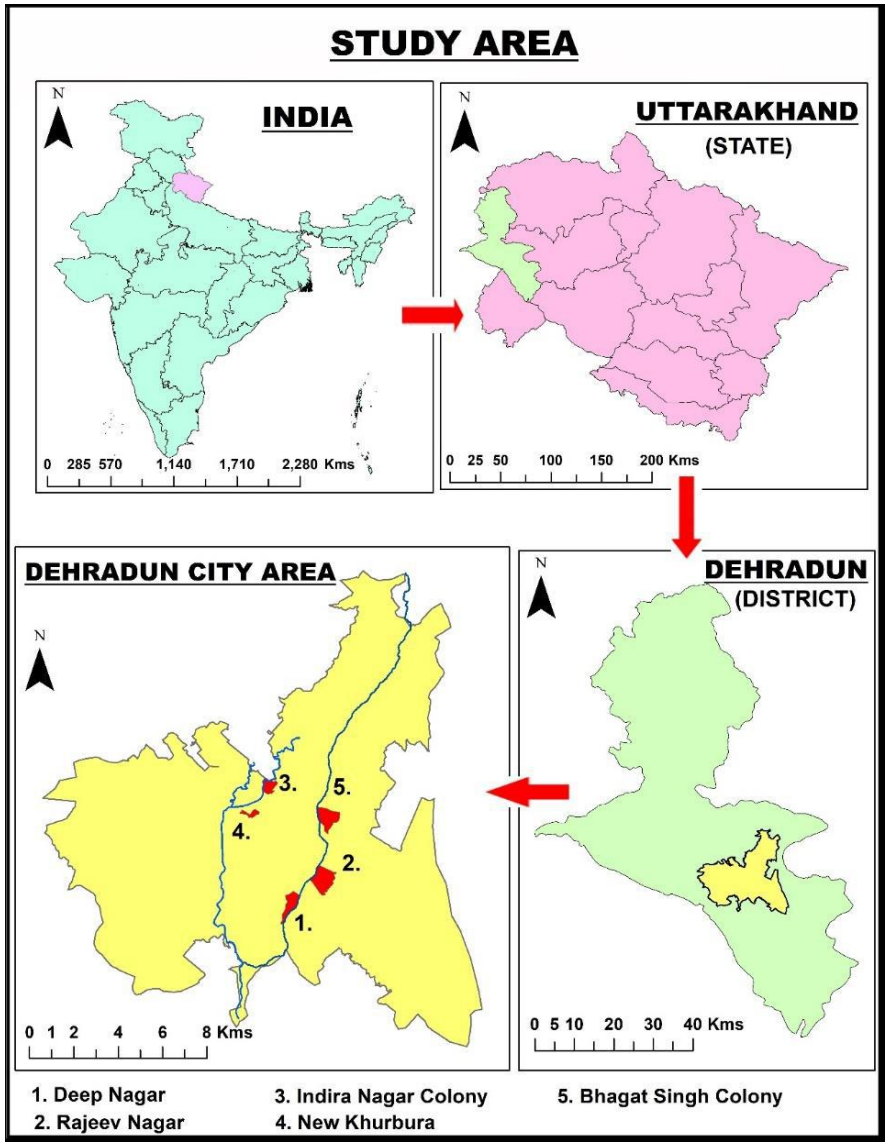

Fig. 1. Selected Slum Sites for the Study in Dehradun City Area

Results and Discussion

Status of Drinking Water Contamination during Pre and Post Monsoon

Drinking water samples from point of use were analysed for the presence of Total Coliforms and E. coli. According to the guideline values for the bacteriological quality of drinking water by the World Health Organization, all water intended for drinking must not be

detectable in any 100 mL sample with Total Coliform Bacteria and E. coli (WHO 2017). The results revealed higher MPN per 100 mL samples in case of Total Coliforms and E.coli which indicates for the high faecal contamination in the water supply lines. During the pre-monsoon days, the mean value for the Total Coliform present was 174.8 per 100 mL with the standard deviation of 112.3 but these values increased enormously during the post-monsoon days i.e. 1,129.5 per 100 mL with the deviation of 970.3.

Table 2. Water Quality at Point of Use at different Slum Locations (as of May and August)

Slum	Water Contamination Indicator			
	Average Total Coliforms		Average E.coli	
	Pre	Post	Pre	Post
Deep Nagar	326.6	2,210.7	17.25	10.55
Rajeev Nagar	59.25	227.5	1.1	17.35
Indira Nagar Colony (INC)	284.2	2,260.9	1.9	30.7
New Khurbura	97.5	625.8	57.7	38.75
Bhagat Singh Colony (BSC)	106.6	322.8	16.6	14.5
	174.8±112.3	**1129.5±970.3**	**18.9±20.7**	**22.4±11.7**

Source: *Water Testing Results from the Laboratory*

The risk of contracting water-borne illness increased due to high values in the post-monsoon month. Total Coliform with the highest recorded value of 2260.9 per 100 mL was found in Indira Nagar Colony during post-monsoon days only as shown in (Table 2). The E.coli mean values for the pre-monsoon days was found to be 18.9 per 100 mL. For post-monsoon days the mean value for E.coli also increased considerably i.e. 22.4 per 100 mL with the standard deviation of 11.7. From the results, it can be derived that the highest of all the recorded values in case of Total Coliform and E.coli was found in post-monsoon days. As we know Children are more susceptible than adults to the action of bacteriological toxicants, thus it became very important from the health point of view especially for the children belonging to 0-5 age group.

Water Borne Diseases among Children

A poor water supply impacts health by causing acute infectious disease episodes. The quality of water-related to the pathogens and bacteriological constituents in water that can give rise to both diarrheal and non-diarrheal diseases. As the health status of children aged 0-5 years portrays the overall impact due to any of social impairments (income, literacy, filtration knowledge) and environmental impairments (surrounding area, physical location, house type) pertaining to the society, we collected information on the prevalence rate of selected water-borne diseases and the total number of cases affected by water-related diseases was correlated with various factors. Out of the total 150 households surveyed, 180 children was found between the age of 0-5 years and among them, 150 was found to be severely sick. On an average one children per household were found ill. The illness reported in this paper, however, does not necessarily constitute clinically confirmed cases as merely reported by respondents. Due to various social and public awareness reasons, few respondents were also shown reluctant, giving vague or even exaggerated

figures while reporting for the illness that may have caused any deviations from the real situation. Nevertheless, the result obtained, in gross, seems adequate enough to reveal the type of water-borne diseases and the contributing factors impacting the health of the children. Prevalence of water-related diseases: In order to take account of the seasonal impact on the occurrence of water-borne diseases, we considered the point prevalence rate of six diseases that were commonly found. The details of diseases incidence and there prevalence rate per 1000 population of children is presented in (Table 3). Out of 150 households, 150 children of 0-5 years of age was found ill. The number of Diarrheal cases among the children was maximum in all the sampled slums. Out of the total, 45 per cent of the children was suffering from Diarrhea. 19 per cent of children were found ill due to Gastroenteritis. Typhoid affected only 7 per cent of children which was least in number.

Table 3. Prevalence Rate of Six Water-Borne Diseases

Diseases	Cases per 1000 Population of Children				
	Deep Nagar	Rajeev Nagar	Indira Nagar Colony	New Khurbura	Bhagat Singh Colony
Diarrhea	404	386	367	357	278
Gastroenteritis	106	175	200	214	111
Jaundice	106	123	33	71	111
UTI	106	88	67	71	56
Dysentery	64	70	67	71	56
Typhoid	43	70	33	71	56

Factors Affecting Water-Related Disease Burden among Children

Diseases directly related to water contributes significantly to the burden of the disease worldwide. The children population in the slum is at significant risk of water-borne diseases. There are various factors which lead to higher waterborne diseased burden among children.

Table 4. (i) Pearson's Correlation Coefficient Matrix of some Social Factors

Variables	Cases of Water Borne Diseases	Literacy of Parents	Income Levels	Filtering Process
Cases of waterborne Diseases	1			
Literacy of Parents	-0.194	1		
Income Level	-0.726	0.667	1	
Filtering Process	-0.726	0.667	0.987	1

Table 4. (ii) Pearson's Correlation Coefficient Matrix of some Environmental Factors

Variables	Cases of Water Borne Diseases	Physical Location	Surrounding Area	Type of House
Cases of water borne Diseases	1			
Physical Location	-0.194	1		
Surrounding Area	-0.652	0.408	1	
Type of House	-0.581	0.167	0.612	1

A matrix of Pearson correlation coefficients is set up in order to examine the inter-relationships of various factors such as age-wise total number of cases affected by water-borne diseases compared with factors of social impairment (literacy of parents, family income levels and water filtering process) (Table 4 (i)) and environmental impairment (the area surrounding the slum, physical location of the slum) (Table 4 (ii)). Correlation coefficients reveal that it is not only one but many factors that are causing a higher number of water-related disease burden. The Literacy of parents, family income levels and filtering processes adopted by families to filter drinking water in slums: physical location of the slum, surrounding area and type of house, all are negatively correlated with the registered number of cases with waterborne disease and is shown in (Table 4 (i) (ii)). Majorly Low-income levels of the families, poor or no drinking water filtration process adopted by the families having children and the surrounding areas are affecting the most.

Access to Public Health Curative Service among Slum Dwellers

Millions of children die from treatable conditions in most of the developing countries such as India. Three diseases (all preventable and treatable)-diarrhoea, pneumonia, and malaria—are responsible for 52% of child deaths worldwide (Wagstaff and Claeson 2004). Child deaths can be reduced by 63% only if coverage rates of effective prevention and treatment interventions were to increase from current levels to 99% (Jones et al.2003). If we go by the demand side, factors like cultural and educational may obscure the recognition of illness and the benefits from health care, while economic factors may suppress utilization and benefits if recognized. Unavailability of appropriate health services especially in the urban slums of our country could be treated as a factor for the supply side. The study endeavoured to study the perception of slum dwellers regarding the accessibility and barriers to public health services when the children in their family fells sick.

Treatment Seeking Behaviour

During the survey, it was found that majority of families whose children was found sick preferred non-governmental sources for the treatment as shown in (Table 5). Out of the total 150 families, only 39 families (26 per cent) had gone to the Government hospital and government dispensary for the treatment. The private clinic, hospitals and drug stores were the most preferred source for medical treatment. Contrary to expectations, 23 per cent of families sought treatment from alternative systems of medicine such as homoeopath or other traditional healers.

Satisfaction with the Public Health Services

Most of the families living in slums were dissatisfied with the health facilities provided by the government in comparison to private facilities as shown in (Table 6). 19.82 per cent of the families were dissatisfied with the private health facilities whereas 38.46 per cent of families were dissatisfied with the government health facilities.

Table 5. Treatment Seeking Behavior among Slum Dwellers

Place of Last Treatment	Frequency	Percentage
Govt. Hospital	28	18.7
Govt. Dispensary	11	07
Private Hospital	18	12
Private Clinic	36	24
Hakim/ Homeopath	24	16
Traditional Healer	10	07
Drug Store	23	15.3
	150	100

Table 6. Level of Satisfaction with the Public Health facilities Among Slum Dwellers

Place of Last Treatment	Satisfied (%)	Not Satisfied (%)	Total (%)
Government	24 (61.54)	15 (38.46)	39 (100)
Private	89 (80.18)	22 (19.82)	111 (100)
Total	113 (73.33)	37 (24.67)	150 (100)

Various Barriers in Accessibility to Public Health Services

A large number of slum dweller families were dissatisfied with the public health facilities and there existed various reasons which are shown in (Table 7)**.** The most common barrier was too long waiting time and poor quality of care at the public health centres. Too long waiting time causes daily wagers to loss their wages due to the longer time spent in hospitals. Also because of longer distances from residences to government hospitals, cost of transportation became a major barrier. Various other reasons such as rude behaviour of staff in government hospitals, affordability and absence of health personals during the time of visit were other barriers which were forcing people to get some other options for the treatment of their children. There was a large number of people among the slum dwellers dissatisfied with the public health curative services.

Table 7. Barriers to access to public Health Facilities as perceived by Slum Dwellers

Reasons for Dissatisfaction	Percentage
Waiting Time Too Long	38
Affordability	6.2
Poor Quality of Care	22
Distance	18
Absence of Health Personals	3
Rude Behavior of Staff	12.8

Conclusion

As we know safe drinking water is essential for children to survive, to be healthy and for the overall development in terms of both physically and mentally. The study conducted in the slums of Dehradun City showed significantly higher values of Total Coliforms and E.coli during pre and post-monsoon months and thus higher incidence of water-related diseases were found among children of slum dwellers during the post-

monsoon month. The higher number of water-related diseased children aggravated due to the number of factors like lower literacy of parents, lower family income levels, minimal or no knowledge about filtration process of drinking water, location of slums (along *nallah*, along other drains), surrounding area (commercial, railway/ other and institutional) and type of house (Kaccha, semi-pakka and pakka). All factors were negatively correlated with the total number of children suffering from water-related diseases. In spite of these factors, a perception study has been carried out to emphasize the difficulties in accessing the public health curative facilities faced by the population of slum areas. It was found that larger sections of the slum dwellers were not satisfied with the government health institutions due to various reasons. The girth of the problem lies in the fact that Dehradun city population size is expanding rapidly and also slum settlers are rising in numbers. The entire solution may lie in a multi-sectoral approach and achievements including overall socio-economic development of the nation, provision of safe and adequate water facilities in the slums and effective health care facilities for the slum dwellers seems among major issues of immediate concern for reducing the burden of such diseases among children. Also, coordinated efforts among various departments such as water supply department, health department and enforcement department can be encouraged and will play a vital role in addressing the ongoing problems.

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HYDROCHEMICAL ANALYSIS AND EVALUATION OF GROUNDWATER QUALITY IN SOLID WASTE DUMPING SITE IN TIRUCHIRAPPALLI, INDIA

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Abstract

As groundwater is a major resource being utilized to fulfil the requirement of various sectors such as agriculture, industrial and for domestic, it was found essential to check the groundwater quality. Along with the over-utilization of groundwater, solid waste dumping also affects the ground and surface water quality due to the leachates. Hence, in this study, 20 groundwater samples were collected from solid waste dumping site bore wells. Further, the parameters such as pH, EC, temperature, major ions, and nitrate were investigated. Results suggest that, in about 90% of groundwater samples, sodium and bicarbonate are the predominant cation and anion, respectively, and Na-Cl and Ca-Mg-Cl are the major water types in the study area. From, the obtained data it was concluded that the quality of groundwater is not satisfactory and hence the need for the management plan becomes mandatory in order to safeguard the valuable groundwater resources in Tiruchirappalli city.

Keywords: Groundwater, Hydrogeochemical, Stiff Diagram, Cluster Analysis, Box Plot

Introduction

Each community depends on the sustainable utilization of the freshwater resources available. Different forms of freshwater resources are available in the world. And the domestic, agricultural and manufacturing sectors are mainly using the country's groundwater (Sharma et al. 2017). Most of the Indian population (85%) resides in the rural area and get their requirement for water satisfied with the groundwater only. Even the groundwater relies on the irrigation of land too (Selvakumar et al. 2017 and Raju, 1998). With only 4 % of the world's freshwater resources, India supports more than 16% of the world's population (Singh, 2003). However, the groundwater quality is determined by the concentration of the various chemical constituents present in the water and these constituents were found to vary based on the geology of the particular region. Added to this the other factors which pose its influence on the water quality such as the quality of the recharge water, soil - water interaction, soil air-water interaction and also due to rock-water interaction (Selvakumar et al. 2017 and Freeze and Cherry, 1979).

Moreover, the weathering of major and small minerals also contributes to cations and silica ions in the system (Freeze and Cherry, 1979). The geochemistry of groundwater data provides crucial evidence of rock geological history and groundwater recharge and about its movement (Walton, 1970). Natural groundwater quality depends on the geological and geographical structures of the region (Chandrasekar et al. 2014). However, the Groundwater chemistry facilitates us to understand about the hydrochemical assessment of the available groundwater. (Wang, 2013). Such contamination can be statistically interpreted and such interpretation will help us to understand the impact of certain water quality parameters both individually and in combinations.

In the current decade, Cluster analysis (CA) along with the Principal Component Analysis (PCA) and Hydrochemical facies are all recognised to classify variations and sources of contamination in groundwater (Zhang et al. 2012 and Devic et al. 2014). The quality of both surface and groundwater causes long-term environmental degradation due to the discharge of highly polluted industrial waste, along with the overuse of the predominant supply of groundwater (Carneiro et al. 2010). The groundwater quality is however found to get altered during its recharge as it interacts with the soil which if contaminated affects the water too. Further, the leaching and dissolution of industrial wastes also play a major role in affecting the groundwater quality (Rao, 2014). About 80% of the world's diseases and one-third of developed countries' deaths are caused by polluted drinking water (WHO, 2004). The main objective of the present study to discuss the major water quality parameters of solid waste dumping site groundwater in Tiruchirappalli. This was done in terms of the stiff diagram.

Sampling and Measurement

A total of 20 groundwater samples were collected from solid waste dumping sites of Tiruchirappalli districts (Bore wells) for the year (2020) and their physico-chemical parameters were analysed using the standard protocol (APHA,2005). The groundwater samples were collected in 1 litre glass bottles and were refrigerated until further analysis. The analysed parameters include pH, EC, anions and cations. Origin pro 9.1 was used for analysing the correlation matrix and Aquachem Scientific v4.0 software was used for identifying the major hydrochemical facies.

Results and Discussion

Table 1 shows the physical-chemical value of the groundwater samples as well as the box plot in Fig. 1. At the solid waste dumping site in Tiruchirappalli, the average pH was 7.41, with all groundwater samples having a maximum and minimum of 6.78 and 7.94 respectively (BIS 2012). The maximum EC value recorded was 3865 µS/cm and the mean total dissolved solids were about 1186.5 mg/L (BIS 2012). The total alkalinity (as CaCO3) was in the range of 30–120 mg/L (average: 74.5 mg/L), well within the permissible limit of 600 mg/L (BIS 2012).

Table 1. Statistical Summary of Physicochemical Parameters from Collected Groundwater Samples

Parameters	Unit	Minimum	Maximum	Average
pH	-	6.78	7.94	7.41
Electrical conductivity (EC)	µs/cm	676	3865	2309.2
Total dissolved solids (TDS)	mg/l	460	1876	1186.5
Total Alkalinity (TA)	mg/l	30	120	74.5
Total Hardness (TH)	mg/l	160	1230	691.9
Calcium (Ca2+)	mg/l	120	1000	535.25
Magnesium (Mg2+)	mg/l	4.8	94.7	38.04
Chloride (Cl-)	mg/l	79.9	684.7	345.6
Sulfate (SO42-)	mg/l	1.5	233.5	26.41
Nitrate (NO3-)	mg/l	0	26.3	10.03
Bicarbonate (HCO3-)	mg/l	125	1145	624.5
Sodium (Na+)	mg/l	49.4	587.7	226.8
Potassium (K+)	mg/l	1.15	34.2	16.01

Total hardness is imparted by the carbonates, bicarbonates, chlorides, sulphates, nitrates, nitrites of Ca and Mg ions. The total hardness varies as temporary and Permanent too. In this study area, the samples have had their total hardness values ranging from 160 to about 1230 mg/L, calcium ranging from 120 to 1000mg/L. However, the standard value of Ca is reported to be 75 mg/L (BIS,2012). Though Magnesium is reported to be an essential activator for enzyme systems, it is also reported to be cathartic and diuretic. A higher value of Mg ie., about 94 mg/L is also reported in the study area. Both these ions namely the ca and Mg might have been obtained from the dissolution of silicate rock and due to the interaction between the dolomitic deposits and the infiltrating water. Similarly, about 345mg/L of mean chloride concentration was obtained and the mean bicarbonate ion content was about 624 mg/L. The nitrate concentration in groundwater of this area ranged from 0 to 26.3 mg/L with the mean value of 10.05 mg/L. The nitrate ion is reported to be highly soluble in aqueous media and its higher concentration was already reported to result in Eutrophication of water bodies, health condition namely, methemoglobinemia in infants. The main sources of nitrate ion in water include organic matter decomposition, domestic sewage and contamination with fertilizers containing agricultural wastes (David and Gentry, 2000; Tripathi et al. 2000). Sodium (Na) value of the study area ranged from 49 to 587 mg/L with an average value of 226.8 mg/L. The common sources of Na in this region are weathering of minerals like feldspar and application of fertilizers. Potassium (K+) ranged from 1.16 to 34.2 mg/L with an average value of 16 mg/L of the study area water samples.

The stiff diagram represented in Figure 2 shows the number of major cations and anions explain, as well as variations in shape that reflection influence. The existence of various components was evaluated statistically using a Stiff diagram that allows the graphical representation of the major ions present in the water sample (Stiff, 1951 and Singh and Kumar, 2015). Stiff diagrams generally plot the cations on the left of the centre of the middle axis and anions on the right. The cation and anion concentration order is receptive to Na+> Ca2+> Mg2+>K+ and Cl-> HCO3- >SO42->NO3. The units of stiff diagrams are represented by Millie equivalents per litre (meq/L).

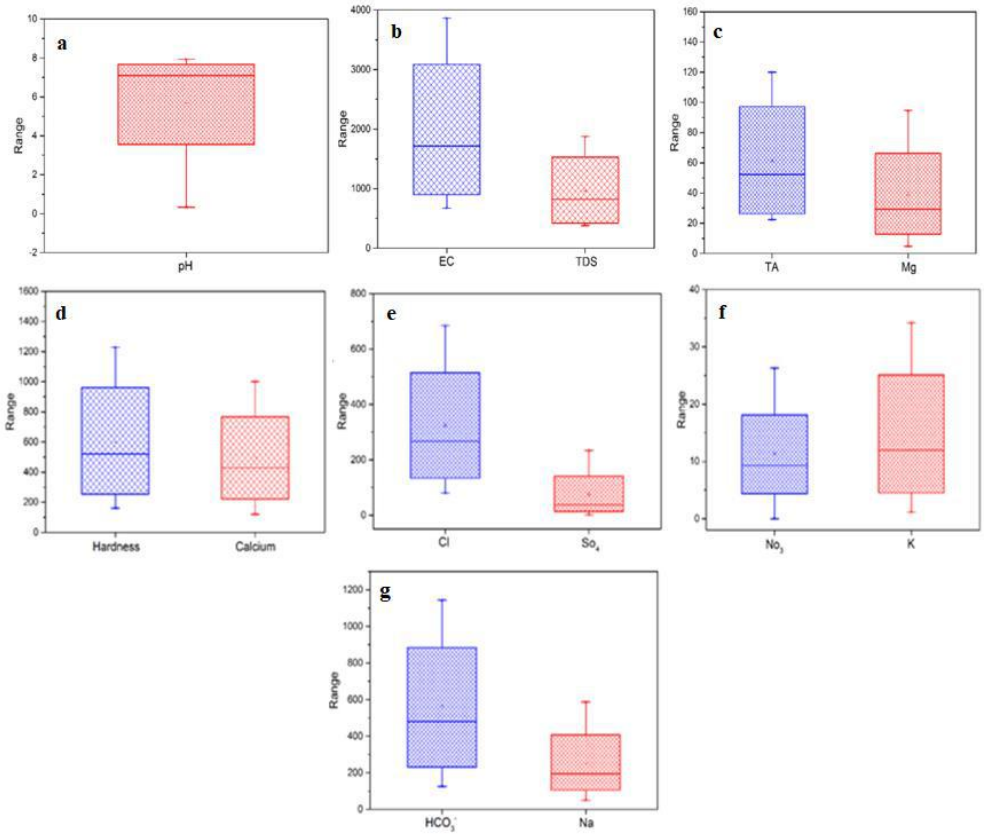

Fig. 1. Box–Whisker Plot of the Groundwater Samples

Figure 2 shows that the cation namely sodium is predominant among cations where bicarbonate is predominant among anions. In addition, four types of groundwater, such as Na-Cl, Na-HCO3, Mg-HCO3 and Mg-Cl are found in this study area. The most predominant water type is Na–HCO3 (about 53.3%) in the study area.

Table 2. Correlation Coefficient for Groundwater Samples

	pH	EC	TDS	TA	TH	Ca	Mg	Cl	So4	No3	HCO3	Na	K
pH	1												
EC	0.723	1											
TDS	-0.566	0.625	1										
TA	-0.511	0.585	0.411	1									
TH	-0.693	0.777	0.834	0.563	1								
Ca	-0.651	0.768	0.758	0.546	0.971	1							
Mg	-0.362	0.258	0.532	0.227	0.398	0.169	1						
Cl	-0.773	0.889	0.735	0.620	0.920	0.919	0.268	1					
So4	-0.413	0.266	-0.092	0.490	0.108	0.096	0.075	0.268	1				
No3	-0.681	0.663	0.764	0.332	0.805	0.753	0.433	0.705	-0.185	1			
HCO3	-0.678	0.768	0.821	0.529	0.995	0.970	0.380	0.909	0.110	0.792	1		
Na	-0.477	0.584	0.472	0.478	0.643	0.687	0.020	0.643	-0.092	0.758	0.614	1	
K	-0.227	0.203	0.365	0.354	0.384	0.357	0.213	0.387	-0.194	0.490	0.341	0.496	1

Bold values indicate good correlation (r > 0.60)

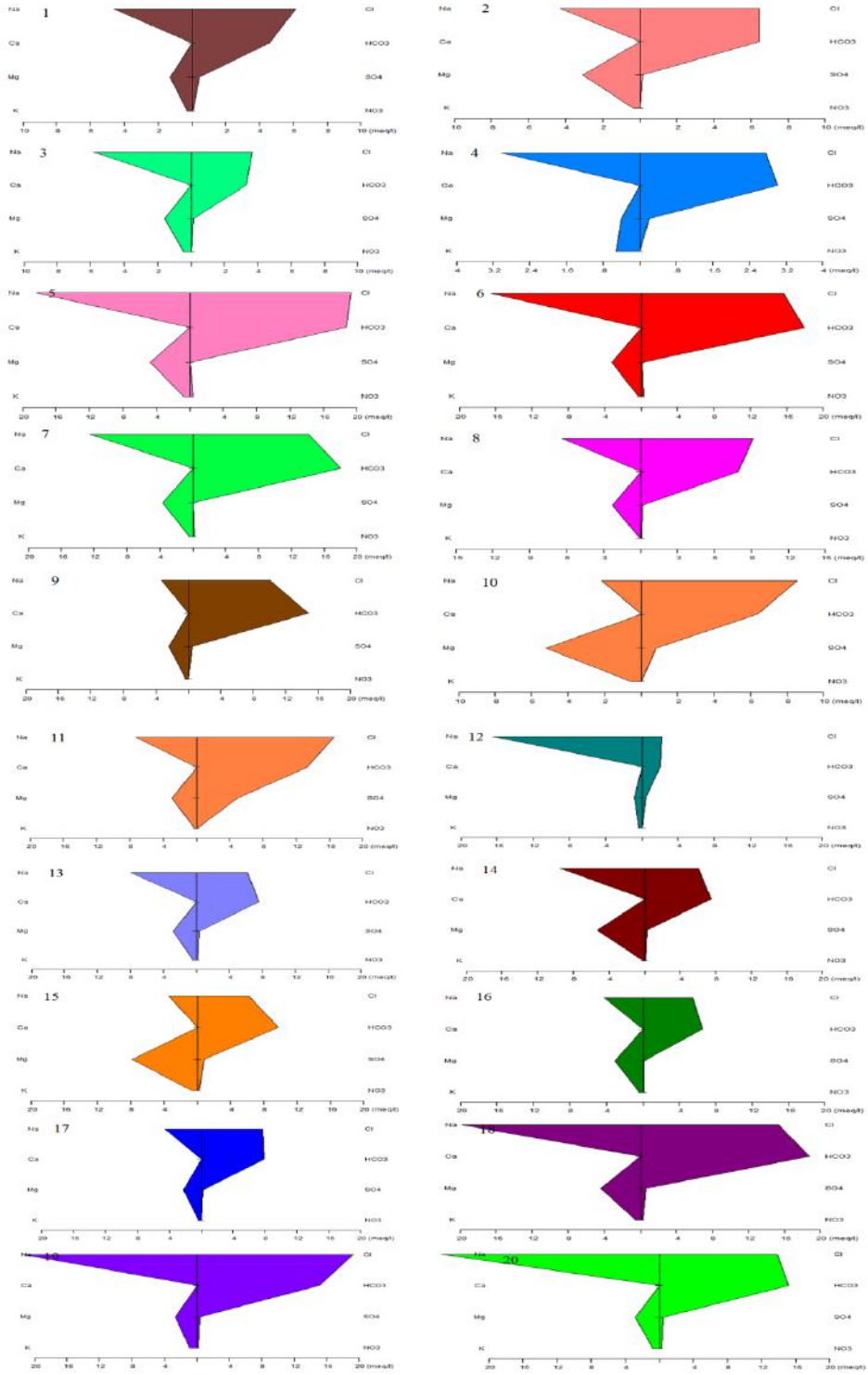

Fig. 2. Stiff Diagram of Groundwater Samples from Tiruchirappalli District

Correlation Analysis

A commonly used assessment to calculate the relationship between two variables is the correlation coefficient. Correlation between major ions was carried out by using Spearman's correlation matrix. Table 2 explains the Correlation coefficient between different water quality parameters. Significant and strong positive correlations (r > 0.7) for TH, Ca, Cl-, NO3 and HCO3 with TDS were obtained based on the spearman's correlation. The strong significant correlation of Ca ion with Cl-(r= 0.920) and HCO3 with Na (r= 0.614) reflects the contamination of groundwater with various contaminants emerging from the anthropogenic activities including agricultural wastes resulting from the excessive usage of fertilizers. The correlation between the parameters makes us understand the complexity of the water quality and however the groundwater contain the mineral substances obtained by the interaction with the soil (Elkrail and Obied,2013). The NO3 ion was strongly correlated with Na (r= 0.758), indicating the possibility of fertiliser contamination, municipal wastewater, septic systems, and grassland cultivation.

Historical Cluster Analysis

This is a category of multivariate methods that mainly classify variables or cases (Massart and Kaufmann 1983) into a cluster with a high level of homogeneity within the class and a high level of heterogeneity between groups.

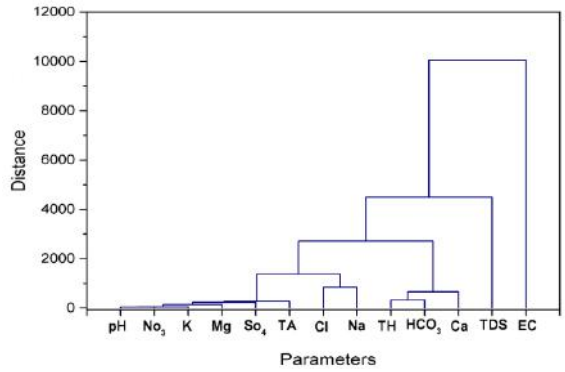

Fig. 3. Parameter Wise Analysis Using Cluster for Groundwater Samples

The CA calculated the spatial variability of groundwater. To classify them into a cluster to minimise their number, CA has first carried out to group all sample sites. In the configuration of a tree with different branches (Dendrogram), we use CA to connect sample sites that have certain homogeneity. In this present study, cluster analysis was applied for the grouping of parameters using the ward's linkage method (Ward 1963). Cluster 1 shows strong similarities between total dissolved solids and the electrical conductivity, which may be due to the addition of minerals to the water system along with the cation exchange process (Figure 3). The presence of TDS in this cluster is an indicator that TDS is affected by cations and anions, thereby increasing the electrical conductivity (EC) of water. Water becomes salty at high TDS concentration (Shahbazi and Esmaeili-Sari 2009).

Conclusion

In this analysis, groundwater samples were obtained from 20 Tiruchirappalli district solid waste dumping sites and parameters of water quality were analysed, such as pH, electrical conductivity, TDS, hardness, calcium, magnesium, chloride, sulphate, nitrate, bicarbonate, sodium and potassium. The highest electrical conductivity, TDS, hardness, calcium, chloride, bicarbonate and sodium above the acceptable limit (BIS) were present in the collected groundwater samples. Hence, the water samples are unsuitable for drinking purposes and we can use other domestic purposes. The following conclusions were drawn the stiff diagram mostly underwater type Na-HCO3. Historical cluster analysis (HCA) reveals that significant utilization of agriculture fertilizer and water-rock interaction are the chief factors affecting the groundwater quality of the study region.

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PROSPECT OF WOOD ASH IN LAND AND SOIL RECLAMATION FOR LIVELIHOOD SECURITY IN DEWAL BLOCK, UTTARAKHAND

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Abstract

Wood ashes are part of human society from an ancient time. Wood ashes could be used in agriculture to manage the pH value of the soil. Forest resources and agriculture are both important to support the life in the mountainous region; therefore, the mountain ecosystem has very limited scope to an expansion of agriculture intruding forested area. It is also true that the mountainous soils are rich in humus, but lack in potash, phosphorous and lime. The present study was conducted in Dewal block represents the possibility of using wood ashes to enhance the fertility of the soil by managing the pH of the soil in the mountain ecosystem as wood ashes are good alternatives to calcium carbonates, CCE (Calcium Carbonate Equivalent) and can help in maintaining Cation Exchange Capacity (CEC). The study was carried out using Stratified Restricted Random Sampling Method to collect primary data for the use of wood for domestic purposes from the selected six villages of Dewal block. The present research will light the benefit of transferring wood from geological cycle to the biological cycle using ashes and biomass for land reclamation and sustaining the soil fertility. This naturalisation will not only support ecological restoration but also encourages afforestation at the higher altitudes and participation of the local community to attain sustainable livelihood.

Keywords: Forest resources, Wood ashes/cinder, Agriculture, Land reclamation, Soil fertility, pH value, Local community, Afforestation

Introduction

The utilisation of the wood ashes to support agriculture has its traces back in the history when human practised traditional agriculture where a patch of land was usually cleared using fire and ashes were left untouched so that soil can regain its fertility using that grounded ash. It caused a serious problem of deforestation because traditional agriculture was not that managed like today. In the 21st century, agriculture is open to much better

technological advancements and growing primary products for consumption purposes are now have become a part of the human culture; therefore, it is called agriculture. Soil is described as a fusion of organic remains, clay and rock particles at the uppermost layer of the earth surface. To grow a healthy crop it is very important to maintain soil fertility. Sustainability of soil fertility directly influences the sustainability of crop productivity and therefore; it is crucial to conserve soil's fertility. Maintenance of soil fertility is only possible with timely soil assessments, controlled productivity and managed application of what is required for the particular soil to sustain fertility. Only with better management techniques of soil, it is possible to sustain the growing population. Reclamation of soil condition is much needed to strengthen small landholding farmers so that they can carry on with their farming activities. Here, the most important thing to note is that the reclamation technique used is to be a sustainable one and it would be much better if the technique engaged in reclaiming soil fertility boosts the growth and development of other natural resources as well as be less heavy to the pockets of farmers.

In the mountain ecosystem of Dewal block, Uttarakhand, every resource is so well interconnected that a mere change in one resource could put great pressure on other resources and that is why mountain ecosystem, in the whole world, is considered to be one of the most fragile ecosystems on the earth. It is due to this fragility, agriculture in the mountains of Dewal are very less open to innovations and expansions. In this regard, it becomes very important to use local resources to maintain productivity at farms. Wood ashes are being used as plant nutrients and are also valuable in raising the pH of the soil. Proper and managed use of wood ashes could help in the proper management of this waste product (if left untreated) and could help as an alternative to chemicals fertilizers which is economically feasible for farmers. Wood ashes are a good source of potassium and phosphorus and could be an alternative to synthetic soil neutralizing agents.

Wood ash being an alternative lime agent can be a good neutralizing agent in maintaining the fertility of acidic soil and are capable of providing a modest amount of K (Potassium) and P (Phosphorus) to the soil (Ohno and Erich 1990). Potassium (K) is the most soluble nutrient in wood ash which is followed by Calcium (Ca) and Magnesium (Mg) and often untreated wood ashes are distributed over the land to increase K and P values of the soil (Meiwes, 1995). Sandy Spodosol showed a significant decrease in Aluminium (Al) with increased nutrient cations and rise in pH level when it was applied with wood ash, where the addition of wood ash also helped in increasing NO_3 in the soil (Kahl, J. S., et al. 1996). Applications of wood ashes can be done as an alternative to agricultural lime but excessive spreading could be harmful to crops but measured spreading for its CCE could be used to maintain farm (Power, et al., 2000). Wood ashes help in the growth of plants as it is a source of phosphorus, calcium, magnesium, potassium and boron (B) and it also helps in reducing the toxicity of Al and Mn (manganese) but as wood ashes, if get mixed with other fertilizers then it can also add to the total nutritional management of the plant growth, most effective in managing the acidifications in tropical acid soils and forest soils (Demeyer et al, 2001). Wood ash applied to the soil helps in the enhancement of pH, Ca, Mg, inorganic C, SO_4, and OH^- ions and it also provides an enhancement of nutrients for

the plant but a high level of basic cation, SO_4 and NO_3, could be a threat to nearby surface water and groundwater if the application of ashes is not at a reasonable rate (Nkanaet al, 2002). Wood ashes are useful agent to provide sustainability to soil nutrients and in protecting forests from further acidification but it is doubtable that who is going to be responsible for the generation and management of wood ashes (Aronsson and Ekelund 2004). When wood ashes are applied on the soil it helps in the fertilization of soil which eventually leads towards an increase in pH value and concentration of dissolved organic carbon (DOC) in the soil which helps microorganisms to enhance their activity (Jokinen et al, 2006). Wood ash by providing 8 to 90 per cent of the total neutralizing potential of lime can help in 45 per cent increased plant growth and has the potential to support plant nutrition as these wood ashes are good sources to potassium, phosphorus and magnesium, and also provide micronutrients to plants which are needed in the trace for the survival; therefore wood ash fertilizer industry could be an opportunity for the agriculture sector and resource conservation (Risse and Gaskin 2010).

The mountain ecosystem is a fragile ecosystem where every resource is interconnected to each other and changing the status of one resource could impact the status of other resources. In the mountain ecosystem of Dewal block, it is a fact that soil is losing its fertility due to increasing pressure to grow more food in limited land. The expansion of the land is almost impossible because to expand agricultural land farmers are needed to intrude in forest land which could have disastrous environmental and ecological consequences. Farmers in the plain areas of India, especially in Punjab and Haryana are using chemicals in their field so harshly that negative impacts on the human and land can be seen varying from direct exposure to farmers including accidental inhalation and ingestion to altering of the food chain and migration of chemicals to water resources nearby farmland. In Dewal block, it is not possible to entertain such high dosage of chemicals to boost soil fertility mainly because these chemicals would flow down the slope and contaminate resources at foothills and plains, further intensifying the problem. Due to the low consumption of chemicals in maintaining the farms, Uttarakhand is known as an 'Organic State' declared by the Uttarakhand government, therefore, farmers are needed to look for the locally available resources to maintain the soil fertility at their land.

Study Area

At 30° 3' 39.9594" E and 79° 34' 37.92" N in Chamoli District of Uttarakhand, Dewal block is one of the 10 blocks of the district having the mountainous ecosystem. Dewal block is constituted of 74 villages out of which a total of six villages were selected to carry out the study on the Utilisation of properties of the wood ashes to sustain soil fertility in the block. The study was carried out using Stratified Restricted Random Sampling Method to collect primary data for the use of wood for domestic purposes from the selected six villages of Dewal block. Selection of the villages is based on altitude and degree of angle of the slopes. On the gentle slope, villages are large size and more populated as compared to a steep slope.

The six villages which were targeted are Ghesh, Bank, Mundoli, Sawad, Phaldiya, and Ulangra (Figure 1). The elevation at Dewal block ranges between 1,500 meters to 2,500 meters and the temperature reaches freezing points at the higher altitudes whereas, it remains between 10 degree Celsius to 30 degree Celsius at lower levels. Dewal block has a thick forest cover and most of the population is involved in a rudimental type of farming and major proportions of the products are subsistence in nature. The study was conducted to understand the prospect of the Utilisation of wood ashes to support the soil of Dewal block as well as the environment and economy at a larger scale.

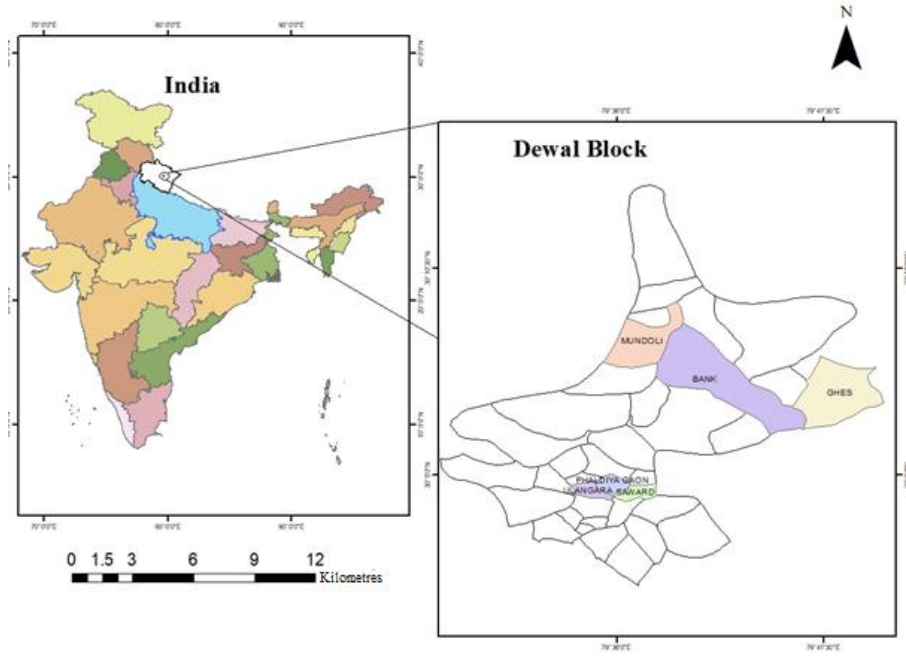

Fig. 1. Location of the Dewal Block

Database and Methodology

The study was conducted to collect primary data which was provided authenticity using data from the various secondary sources. The data were carefully analysed using mapping and statistical software. The data was prepared based on records obtained from 90 respondents of six villages. With the help of the sampling method used in-depth interviews were conducted based upon a structured questionnaire to record the responses of the respondents regarding the consumption of wood in their day to day lives. Governmental websites and other secondary sources were used to obtain data related to population, land use and productivity from agriculture. Data from Census of India, Statistical department of Dehradun and official website of Chamoli district was extracted. The Digital elevation model of the study area was prepared using SRTM-DEM and land use map was prepared using Sentinel image, both obtained from the United States Geological Survey: Earth Explorer website.

The map obtained from the source was processed using ArcGIS 10.3 and ERDAS-Imagine 2014. The use of Surfer-15 was also used to prepare a 3D model of the elevation. Research questions raised were; (i) can wood ash be an option for farmers of Dewal block as a soil amendment, (ii) prospect of wood ash supporting the economy of Dewal block to encourage the strengthening of livelihood and (iii) is it possible that managed consumption of wood ash in the field can support afforestation as well.

Results and Discussion

Land use/Landcover

Dewal block having a mountainous ecosystem comprise of a fragile ecosystem dominated with primary activities; especially, gathering and agriculture. The six villages of Dewal block shows the dominance of forest cover over the cultivated land (Table 1). In Sawad village forest covers 42.9 per cent of the land whereas cultivated land covers 35.18 per cent. In Phaldiya village per cent share of forest in total available land for the village is 32.80 per cent and cultivated land covers 59.08 per cent. Ulangra has a forest cover of 6.44 per cent whereas cultivated land is 33.55 per cent. Ghes village has the highest proportion of the forested area among the rest of the five villages and covers 61.28 per cent of the land whereas cultivated land covers 26.70 per cent. Bank and Mundoli villages have a forest cover of 55.45 per cent and 58. 17 per cent and cultivated land in these two villages are 12.84 per cent and 30.27 per cent (Figure 2).

Table 1. Forest Cover of Surveyed Villages, Dewal Block

Name of the Village	Land available	Forest Area (in Hectares)	Cultivated Land (in Hectares)
Sawad Village	317.95 ha	136.5	111.88
Phaldiya Village	59.14 ha	19.4	34.94
Ulangra Village	98.61 ha	6.36	33.09
Ghes Village	339.34 ha	207.98	90.62
Bank Village	412.69 ha	228.84	53.03
Mundoli Village	337.93 ha	196.59	102.32

Source: *District Census Handbook-2011, Chamoli.*

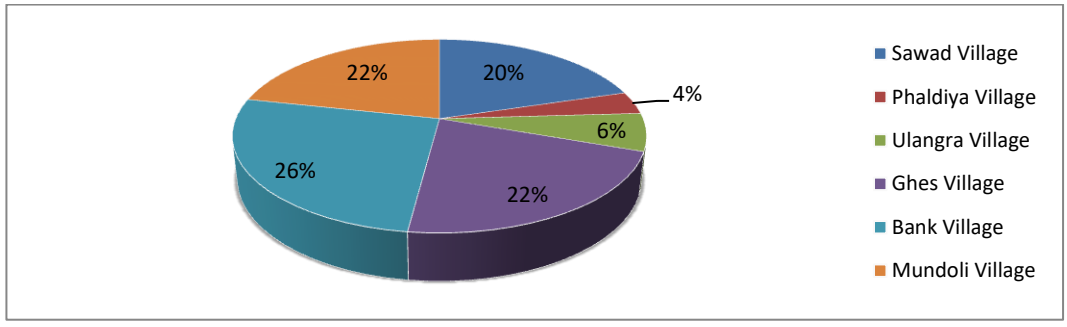

Fig. 2. Land Availability of Six Villages of Dewal Block (in Ha.)

Source: *District Census Handbook-2011, Chamoli, Chart prepared by Authors*

The share of forest and agriculture land in the study area shows the interdependency of two different resources on each other in a mountainous ecosystem. (Figure 3 and 4). In the survey, it was found that around 50 per cent of the villagers are engaged in primary activities of gathering and agriculture in Sawad village. Similarly, in Ulangra and Phaldiya Gaon, there are around 43.33 per cent of the villagers engaged in primary activities and Bank, Mundoli and Ghes shares 16.16 per cent of the farmers working on fields for the livelihood.

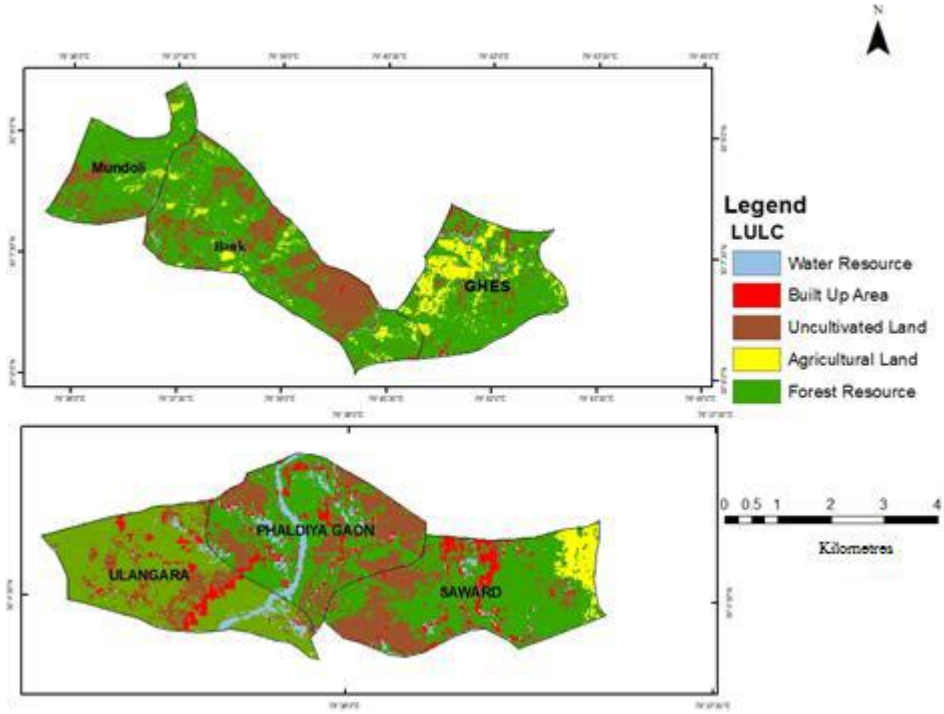

Fig. 3. Land Use/Land Cover of Six Villages of Dewal Block

Source: *Compiled by Authors based on Sentinel Image, United States Geological Survey 2019.*

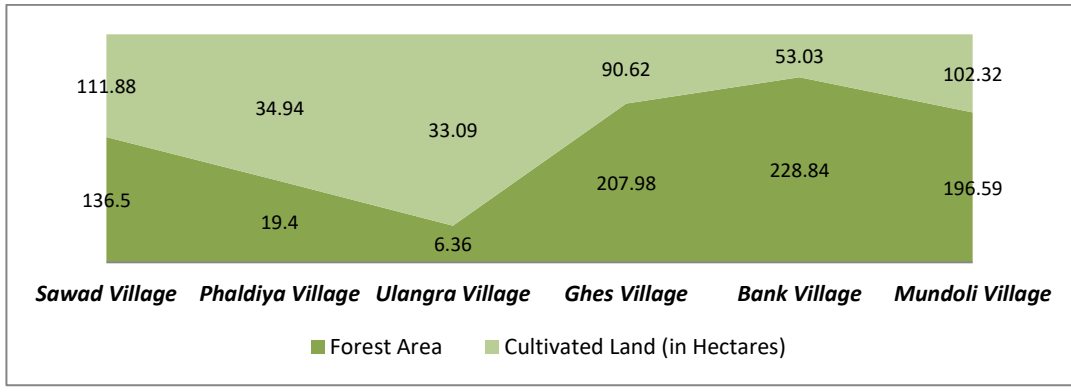

Fig. 4. Land Use/Land Cover of Six Villages of Dewal Block

Source: *District Census Handbook-2011, Chamoli, Chart prepared by Authors*

Consumption of Wood

In the survey, it was found that people of these six villages in Dewal block are engaged in zero chemical farming and farms are being managed under the organic farming system. Farmers of Dewal block are practising the farming using locally available resources. It was also found that Nali is the measurement unit being used in the area to demarcate the land measurement. There are around 37 respondents who are practising farming using locally available resources on their land of 1 Nali to 2 Nali. Here, it is important to note that 1 Nali is equal to 0.0201 ha or 0.0496 acres. 28 respondents agreed that they are maintaining their farms, which are between 3 Nali to 5 Nali, using their livestock and exploiting forest resources. 13 respondents are not having a single piece of land under their ownership while 11 respondents were found having more than 5 Nalis but less than 10 Nalis of land under their ownership. In Ghes there was only 1 respondent having the ownership of more than 1 Nalis of land.

Forest resource being dominant in the ecosystem of Dewal block plays an important role in supporting the livelihood of local people. Wood obtained from the nearby forested land is a major source of fuelwood in the rural and agrarian society of the six villages of Dewal block (Pandey et al., 2017). It was found during the survey that on an average a local in the study area spend approximately 2 to 3 hours in the forest collecting wood and other products from forests to support their livelihood (Figure 5).

It was also found that there are 17 respondents those who find it necessary to visit forest twice every day to collect wood to support fire in the kitchen and fodder for their livestock. Out of these 17 respondents visiting the forest twice daily, the majority were found in Bank village showing a high level of dependency on the forest to maintain the farm inputs and fuelwood supply for domestic purposes. Out of all the respondents surveyed 23.33 per cent of respondents visit the forest to collect wood at least once per day. Only 6.66 per cent and 5.55 per cent of the respondents were found visiting forest once in 5 days and once in a month (Table 2).

Fig. 5. Collection of Fodder and Fuel wood in Dewal Block

Source: *Fieldwork 2019*

Table 2. Dependency on Forest for Fuelwood and Fodder

Time	Phalidiya	Ulangra	Sawad	Bank	Mundoli	Ghes
Twice a day	00	02	04	09	01	01
Once a day	01	05	05	03	05	02
Once in 2 days	02	03	02	01	04	02
Once in 3 days	07	02	01	01	02	04
Once in 5 days	01	01	01	00	01	02
Once in a week	03	01	01	01	01	03
Once in a month	01	01	00	00	01	01

Source: *Fieldwork, 2019*

When wood from the forests is utilized as fuelwood and for fire especially in winters it produces ash. Wood ash is the remaining of burnt wood which is inorganic and organic. Wood ashes are considered as rich in calcium and other micronutrients needed for the growth of plants. Wood ash contains Nitrogen, Phosphorus and Potassium in 0-1-2. It is also a fact that burning of wood produces 6 per cent to 10 per cent of the wood ash. Wood ashes can be used in agricultural fields to maintain the crops as low analysis fertilizers as K, or liming agent and it is less expensive for farmers and more environmentally friendly is managed properly. People move to the nearby forest area to collect wood for fuel and heating (Singh and Pandey, 1995). The survey revealed that 77.77 per cent of the population use Hardwood lying on the ground for combustion and only 22.22 per cent people take fresh wood for combustion (Table 3 and Figure 6).

Table 3. Source of Fuelwood

	Number of Respondents	
Name of Villages	**Fresh wood**	**Hardwood**
Phaldiya Gaon	3	12
Ulangra	7	8
Sawad	2	13
Bank	3	12
Mundoli	4	11
Ghes	1	14

Source: *Fieldwork, 2019*

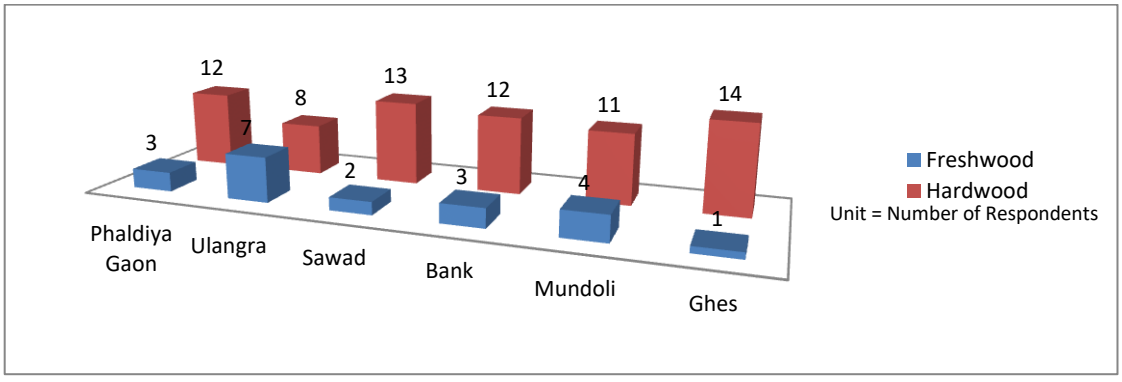

Fig. 6. Source of Fuelwood

Source: *Prepared by Authors, 2020.*

Wood ash contains 10 per cent potassium and 1 to 2 per cent phosphorus but the range declines if softwood is being utilized. This means that a hard and dry wood which is almost dead produces more liming effect compared to the softwood and have more nutrients to provide to the soil. During the survey, it was also found that the reason behind collecting hard and dry wood from the ground is for protecting deforestation (Harish et al, 2019). Villagers by collecting the remainings from the forests show their respect towards the forest as for these local people forest is a sacred entity. When surveyed, it was found that 76.66 per cent of the respondents are still using wood for cooking in the six villages. It is a fact that a majority of people in the villages are turning to 'Ujjawala Yojna', due to which consumption of wood registered a fall thus, discouraging deforestation but still there are some respondents who prefer using wood for cooking on special occasions especially if there is a puja in the house (Table 4 Figure 7).

Table 4. Consumption of Wood in Kitchen in Dewal Block

	Number of Respondents	
Name of the Villages	**Yes**	**No**
Bank	14	1
Mundoli	11	4
Sawad	8	7
Ulangra	12	3
Phaldiya Gaon	9	6
Ghes	15	0

Source: *Fieldwork, 2019*

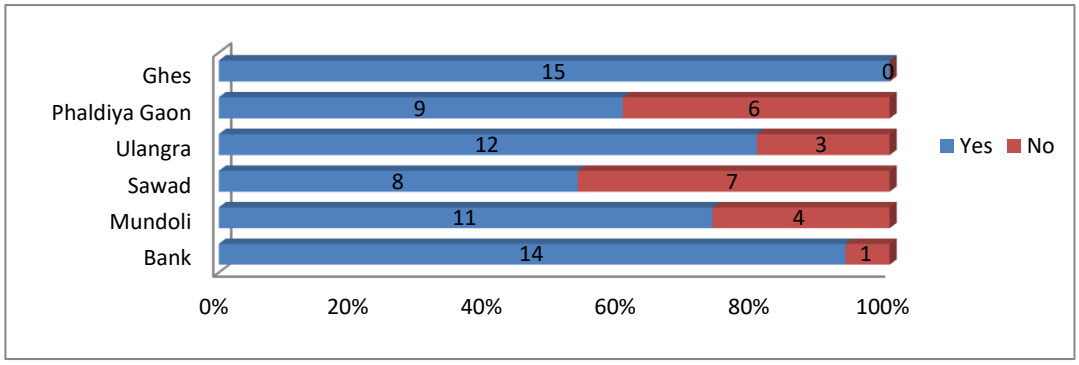

Fig. 7. Source of Fuelwood

Source: *Prepared by Authors, 2020*

In the survey, it was also found that most of the people prefer outmigration to lower levels to avoid the harsh winters of Dewal block. The cases of outmigration are high in Bank, Mundoli and Ghes villages as they are subject to very low temperature during winter and snow is responsible for their crop loss as well. To face such a harsh winter 90 per cent of the respondents of the six villages prefer using wood to produce heat for themselves as well as for their livestock. Only 10 per cent of the selected respondents do not use wood for heating, rather, either they out migrate or they are using heaters in winters, particularly in Sawad, Ulangra and Phaldiya Gaon (Table 5 Figure 8).

Table 5. Consumption of Wood for Heating

	Number of Respondents	
Name of the Villages	**Yes**	**No**
Bank	14	1
Mundoli	12	3
Sawad	13	2
Ulangra	13	2
Phaldiya Gaon	14	1
Ghes	15	0

Source: *Fieldwork, 2019*

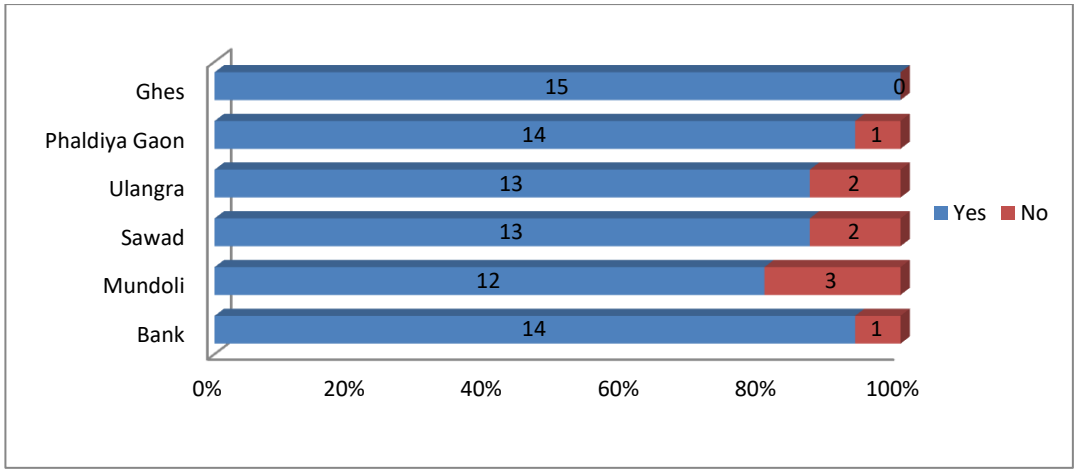

Fig. 8. Source of Fuelwood

Source: *Prepared by Authors, 2020*

Consumption of Wood Ashes

Our ancestors identified the use of ashes, therefore, they started to slash and burn forests for expansion of agriculture because they became aware of the capability of ash in increasing the fertility of the soil. Now, it is not possible, also not a correct technique to slash and burn the forests to expand the land for agriculture as it will promote deforestation. But, in mountainous ecosystem consumption of wood is very common, especially in winters to produce fire for heat especially to keep livestock warm. The utilisation of wood in Dewal block is also a very common process to produce heat, especially in winters. In villages that are at some altitude, like Bank, Mundoli and Ghes, burning of wood is still dominant to produce heat for various purposes like cooking, heating, to keep wild animals away, etc. Wood ash has the property of lime, thus act as a liming agent but villagers are not aware of the scientific fact so they are following the way of their ancestors. From a very long time, villagers are using wood ash for their farms to enhance the fertility of the soil. They mix the burnt ash with cow dung and homemade manure to spread it over the field. In this way, villagers deal with infertility and pests responsible for the degradation of soil as well as crops (Figure 9).

Wood is a free resource to increase soil pH as it is a source to phosphorus, calcium and magnesium which are essential for plants' growth and to introduce lime to their field, farmers need to purchase it from the market and it will put pressure on farmers pocket. It was found in the survey that 82.22 per cent of the respondents prefer using wood ash mixed with cow dung to maintain the fertility of the soil and only 17.77 per cent of the respondents do not use wood ash in their farms because they do not use or they do not prefer using wood and wood ash for the household and farms. (Table 6 and Figure 10).

Fig. 9. Generation and consumption of Woodash in Dewal Block

Source: *Fieldwork, 2019.*

Table 6. Consumption of Ash for the Maintenance of Farm in Dewal Block

	Number of Respondents	
Name of the Villages	**Yes**	**No**
Bank	14	1
Mundoli	12	3
Sawad	13	2
Ulangra	11	4
Phaldiya Gaon	10	5
Ghes	14	1

Source: *Fieldwork, 2019*

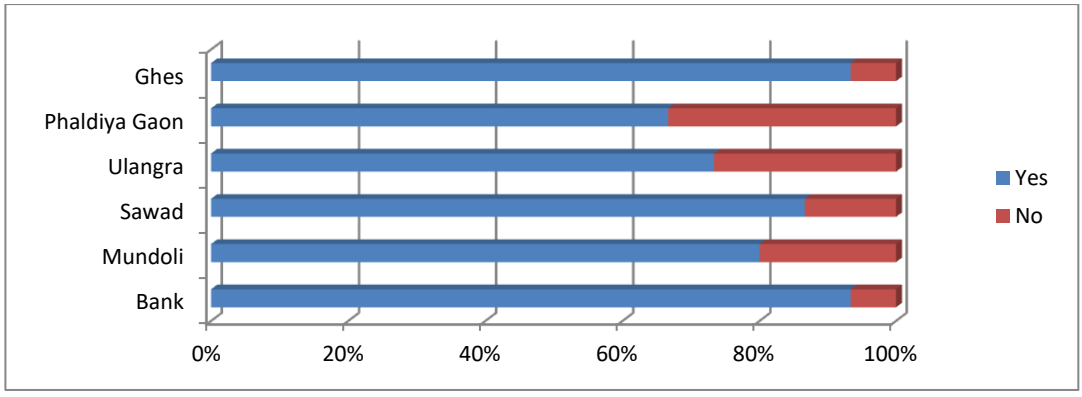

Fig. 10. Consumption of Ash for the maintenance of farm in Dewal block

Source: *Prepared by Authors, 2020*

Wood ash is found to be only half as effective as a lime application in the soil but benefits of wood ash application can be enhanced by adding it with other locally available supplements, especially those obtained from the livestock, for example, cow dung. It was estimated that an average cow can produce approximately 80 pounds of fertilizing substance per day. In the survey, it was found that organic farms of the six villages of Dewal block are supported with good availability of livestock. Cow being dominant covers 43.86 per cent of the total livestock population followed by the buffaloes which are 40.56 per cent of the total livestock population. Sheep, Goats and Horses also support the livelihood and farm of the villages from an economic point of view (Table 7).

Table 7. Livestock Distribution in Surveyed Villages

Type of Animals	Phalidiya Gaon	Ulangra	Sawad	Bank	Mundoli	Ghes
Cow	15	10	15	15	20	18
Buffaloes	15	10	15	15	15	16
Sheep	3	1	0	3	2	4
Goats	2	3	1	1	5	2
Horses	0	1	0	3	1	1
Others	0	0	0	0	0	0

Source: *Fieldwork, 2019*

Apart from using wood ash mixed with homemade manure to deal with infertility and pests on the farm, it can be used to melt ice in winters. Wood ashes can melt ice, it might be not that effective as salt but in this way, we can properly utilize the ashes. Wood ash is environment friendly and does not harm the local ecosystem if it is managed properly. In ancient times, wood ashes were used by our ancestors to create detergent to wash metals and cloths, even today in Indian households, especially in rural areas as well as in some urban areas, housewives use ash to clean utensils and jewellery.

Conclusion

Dewal block is resting in a fragile ecosystem where every resource is interconnected with each other. The mountainous ecosystem of the block does not allow agricultural expansion, deforestation and advancement of technology in the agricultural sector. Soil fertility is also not static and keeps changing with the fluctuations of pressure to produce on it. Soil plays an important role in supporting the ecosystem which is dominantly based upon the natural parameters. In the study area, most of the produce is subsistence in nature and are self-consumed by the people of the block; which indicates the low income of the farmers to buy expensive technologies and inorganic inputs from the market to support their farm to produce more. Application of wood ash in the agricultural field can help a farmer to maintain the health of the crop as wood ash can provide many micronutrients essentials for the healthy growth of the crop. Wood ash application is rich in P and K and can also help in regulating the pH of the soil in farms as well as in the forest grounds. Wood ash is also a very good source of calcium and manganese which are essential for soil to maintain the pH level and these elements give wood ash the characteristics of liming agent.

Wood ash as half effective as lime but its properties as a fertilizer can be enhanced if it is mixed with the cattle manure. Cow dung is being utilized in the farms of Dewal and it is also found in the fieldwork that cow dominates the farms with 45.53 per cent of the livestock population. This makes wood ash environment-friendly as well as pocket friendly to the farmers. It is also very important to have soil tests at regular intervals before the application of wood ash to the soil. Wood ashes contain some toxicity which must be avoided with the proper and managed application of wood ash to the soil which is only after the regular soil tests. Farmers from different parts of the world reported the success of wood ash application when it is done mixed with the natural manures prepared using on-farm resources. Wood ash production seems to be a bright future because consumption of wood is not recent phenomena in the block and people were relying on the wood for fuel in the area from a quite long. A governmental project like “Ujjawala Yojana" is promoting the use of LPG in the kitchen which is saving the wood consumption in the villages and this quantity of wood can be used to enhance the fertility of the soil with a proper and strict management system. Refined wood ashes are good alternatives to calcium carbonates, CCE (Calcium Carbonate Equivalent) and can help in maintaining Cation Exchange Capacity (CEC) if mixed with other manures and can be put in the market for selling which can boost the economy of Dewal.

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THE CHANGING APPROACH TOWARDS DEVELOPMENT PLANNING - A CASE STUDY OF CHENNAI METROPOLITAN AREA, TAMIL NADU

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Abstract

Tamil Nadu is the most urbanized state in the country, with 48.45 % of its population living in urban areas as per the 2011 census. The history of contemporary planning practices in Tamil Nadu dates back to the enactment of the Tamil Nadu Town and Country Planning Act, as early as 1920, based on the visit of Patrick Geddes to the city of Madras in 1916. Both this Act and the subsequent Act (enacted in 1971) provide for the preparation of various types of plans- to guide and regulate the growth of development in an orderly manner. The Chennai Metropolitan Area has been the focus area for the preparation of various plans, and an attempt has been made in this paper to chronicle the various plans prepared for Chennai Metropolitan Area based on the statutory provisions prevalent in the respective period. The objective of the paper is to understand the content of all these plans and the present focus of development planning in the Chennai Metropolitan Area.

Keywords: Master plan, Town Planning Schemes, Urban Development, Grid of Roads, Detailed Development Plan

Introduction

Tamil Nadu is the most urbanized State with 48.45% of the population living in urban areas as per the 2011 census. The urban population has increased from 14.15% in 1901 to 48.45% in 2011. The state has a long history in the realm of Development Planning, especially since the passing of the Madras Town Planning Act, as early as 1920. The initial thought for Town Planning legislation for the then Madras Presidency was first mooted by Government of India in 1909. The visit of Patrick Geddes to Madras city in 1914 on an invitation from Lord Pentland (Governor) to study the problems of the city of Madras resulted in organizing town planning exhibitions and lectures in Madras city. Patrick Geddes can truly be called the 'Father of Town Planning' not only in the Madras city but throughout India. In 1915, on the advice of Patrick Geddes, H.V.Lanchester, one of the Vice Presidents of the Royal Institute of British Architects at that time, was appointed as official Town Planning Advisor. Patrick Geddes and Lanchester were mainly responsible for persuading the Government of Madras to pass the historic Madras Town Planning Act 1920. It was established for the first time, a positive attitude towards the inclusion of urban issues in the

public policy. The focus of Development Planning has undergone several changes and an attempt is made in this research paper to chronicle the various plans prepared for Chennai Metropolitan Area as per statutory requirements focusing on the content of these plans and the present focus of development planning and the process of implementation.

The Madras Town Planning Act, 1920

The Madras Town Planning Act of 1920 was enacted to secure to the inhabitants of the cities, all amenities of a pleasing environment for safe and convenient living and efficient movement of people as well as goods. For this purpose, the Municipal Council was empowered to prepare 'General Town Planning Scheme'. Most of the Municipal Councils, however, were not in a position to take up Town Planning schemes largely due to financial inadequacy.

General Town Planning Scheme 1957

The Town Planning Act 1920 outlined the General Town Planning schemes for the Municipal areas and other local areas within urban centres. The General Town Planning scheme was prepared by the Madras Corporation and submitted to the then Madras Government in 1957. These schemes specified the designated use of different parcels of land and prescribed regulations governing each type of development. The copy of a typical Town Planning Scheme map (Egmore Harrington Road TP Scheme) is given in Figure 1a. It may be observed that the Town Planning scheme provided for land use for the various parcels of land and also had the circulation pattern. In areas not covered by the schemes, the Madras Corporation enacted a set of building rules to regulate the development, and land use was given secondary consideration. This system, however, was not adequate to cope with the development in later years.

The areas for which Town Planning schemes were sanctioned in Chennai city are given in Figure 1b. It may be observed that only 17% of the then city area (129 sq.km.) was covered under sanctioned Town Planning schemes. These schemes, apart from designating various uses, also had a broad circulation pattern with proposals for road widening. The General Town Planning scheme was submitted to the then Directorate of Town Planning, Madras for technical scrutiny. The Directorate of Town Planning, after careful scrutiny of the scheme, had recommended that a more detailed and extensive study in-depth would have to be carried out before the scheme could be finalized. It was decided to prepare a comprehensive development plan for the then Madras Metropolitan Area and to prepare the Madras Interim Plan in the first instance.

The Town Planning schemes were followed by the Madras Interim Plan in 1967 and the Madras Metropolitan Plan in 1971. The Tamil Nadu Town and Country Planning Act was passed in 1971; the Chennai Metropolitan Development Authority was constituted initially as an ad-hoc body in 1972 and was established in the year 1975. Consequent to its constitution, the CMDA prepared the Master Plan for the Metropolitan Area and the same was approved in August 1975.

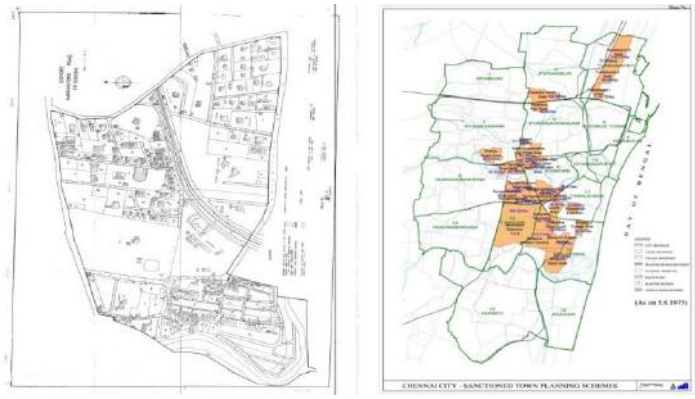

Fig. 1a. Egmore Harrington TP Road b. Sanctioned Town Planning Schemes
Source: *Chennai Metropolitan Development Authority*

Master Plan

The Master plan is one of the most important documents which facilitated and encouraged the optimal growth of dominant functions of urban centres, strengthens the intra-urban linkages and provides an elbow room for spatial growth. The Master Plan lays down the basic framework for guiding and regulating the future growth of an urban area. The Master Plan primarily consists of three basic instruments (a) Land Use Assignment Zoning Plan that determines the use of each land parcel in the development area, (b) Structural Road Network Plan that guides the laying of trunk infrastructure in the development area and (c) Development Control Regulations that determine the built form in the development area.

First Master Plan for CMA – 1975-91

The First Master Plan was prepared by updating the land use Surveys, and Development Control Regulations became part of the Master Plan. The First Master Plan for the then Madras Metropolitan Area (MMA) was prepared for the horizon year 1991 and it laid down policies and programmes for the overall development and for MMA to take a long-term view of the requirements. The First Master Plan adopted the spatial strategy of Development of the Radial Corridors linked to satellite towns and urban nodes with the main strategy focused on decongestion. The Development of Maraimalai Nagar New Town and Manali New Town were an offshoot of the strategy of the First Master Plan for CMA, wherein the CMDA acquired land and implemented the schemes successfully. Apart from these schemes, wholesale markets for perishables, food grains, Iron and Steel, Bus Terminals and Truck Terminals were also developed as part of the decongestion strategy.

The traffic and transportation plan included the construction of the Mass Rapid Transport System, three radial corridors including Inner Ring Road, Intermediate Ring Road and the Outer Ring Roads. Apart from these proposals, the proposed width of the roads was also notified for selected roads in the Master Plan. The area proposed for road widening was earmarked in the plans as and when developments were approved, enabling the concerned local body to utilize such lands for road widening without paying any compensation.

Detailed Development Plans

The Tamil Nadu Town and Country Planning Act, 1971 provides for the preparation of Detailed Development Plans under Sec. (27) of the Act. The Master Plan is generally followed up with the preparation of Detailed Development Plans for smaller areas of about 2-3 sq.km in size. The CMDA took up the preparation of the Detailed Development Plans for Chennai City by dividing the then city's area into grids of suitable size and Detailed Development Plans have been prepared for 56 planning units (Table 1).

The plan showing the grids for Chennai city (Planning Divisions) and the area covered by Detailed Development Plans within Chennai city is given in Figure 2a and 2b respectively. It may be observed that Detailed Development Plans have been prepared for 75.61 sq.km of the city area and it was proposed to cover the entire city with the preparation of Detailed Development Plans in a phased manner.

Process of Preparation of Detailed Development Plans:

The process of preparation of Detailed Development Plans is very time consuming and involves an elaborate collection of data through primary surveys. The content of detailed development plans as spelt out in the rules include

1. A layout plan showing the line of existing and proposed streets
2. The ownership of all lands and buildings in the area to which the plan relates
3. The area of all such lands whether public or private
4. Full description of all details of the plan
5. An estimate of the cost of the plan
6. Regulations for enforcing or carrying out the provisions of the plan
7. Lands belonging to State and Central Governments, local authority and other Quasi-Government agencies
8. The area in respect of which restrictions, if any are proposed as regards to the character of buildings to be erected, whether residential, commercial, industrial and others and the density of buildings, that is the number of dwelling houses to the hectare or the minimum size of the house sites or both. Further, open spaces, recreation grounds and areas where buildings are prohibited. In addition, if any other particulars of plans that may be specially required by the government and levels taken if any, of the area included in the plan with the levels of the surrounding lands.

The rules have also indicated the specific statements that need to the prepared in the prescribed format as part of the Detailed Development Plans and these include Statement showing the ownership and extent of lands, Statement showing the list of new streets and widening of existing streets, Statement showing the lands proposed to be acquired and Statement showing the lands proposed to be reserved.

Table 1. List of Approved Detailed Development Plans

Sl.No.	Name of the DDP	Sl.No.	Name of the DDP
1	Vivekanandapuram Area	29	Todhander Nagar Area
2	GangadeswararKoil Area	30	Nammalwarpet Area
3	Chetpet	31	Thiru-vi-ka Nagar Area
4	Chepauk Area	32	Binni Mill Area
5	Guindy Area	33	Ashok Nagar Area
6	Gandhi Nagar Area	34	Perambur North Area
7	Kottur Area	35	ArunachaleswararKoil Area
8	Periamet Area	36	Thyagaraya College Area
9	Jeeva Nagar Area	37	Rangarajapuram Area
10	Azad Nagar Area	38	Pulianthope Area
11	Krishnampet Area	39	Egmore Station
12	Zam Bazaar Area	40	Perumalpet Area
13	Radhakrishnan Nagar Area	41	Nappier Park Area
14	Kamaraj Nagar Area	42	Government Estate Area
15	Avva Nagar Area	43	Thiruvottiyur TP Scheme No.8 Area
16	Thiruvottiyur TP Scheme No.2 Area	44	Thiruvottiyur TP Scheme No.1 Area
17	Nandanam Area	45	Thiruverkadu Area
18	Urur area	46	Nakkeerar Nagar Area
19	Killiyur Area	47	Kalaivanar Nagar Area
20	Nungambakkam Area	48	Kannadasan Nagar Area
21	Guindy Park Area	49	Rajaji Nagar Area
22	MylaporeSanthome Area	50	Anna Salai Area
23	Karaneeswarapuram Area	51	Vallalar Nagar Area West
24	Thiruvatteeswaranpet Area	52	Vallalar Nagar Area South
25	CIT Colony Area	53	Vallalar Nagar Area Central
26	Amir Mahal Area	54	Vallalar Nagar Area East
27	Marina Area	55	Poonamallee High Road TP Scheme Area
28	Azhagiri Nagar Area	56	Saidapet Park II Area

Source: *Chennai Metropolitan Development Authority*

Detailed Development Plans are normally prepared for two or three sq.km area and such area on an average may consist of several thousands of land parcels for which the ownership details need to be compiled. The collection of ownership particulars are based on revenue records and in many instances several discrepancies are observed between the revenue registry and the site condition. Unauthorized subdivisions of land and encroachments are not recorded in revenue registry and such situation recording of ownership for all lands in a Detailed Development Plan area becomes a complicated process.

Similarly, the status of all buildings in terms of their size and usage also needs to be recorded and this also becomes time-consuming in view of a large number of buildings within the plan area. Even though the First Master Plan for CMA had indicated that Detailed Development Plans would be prepared for all planning units within the city the same could not be taken up due to the elaborate process involved in the preparation and also due to lack of personnel to carry out such detailed tasks and surveys.

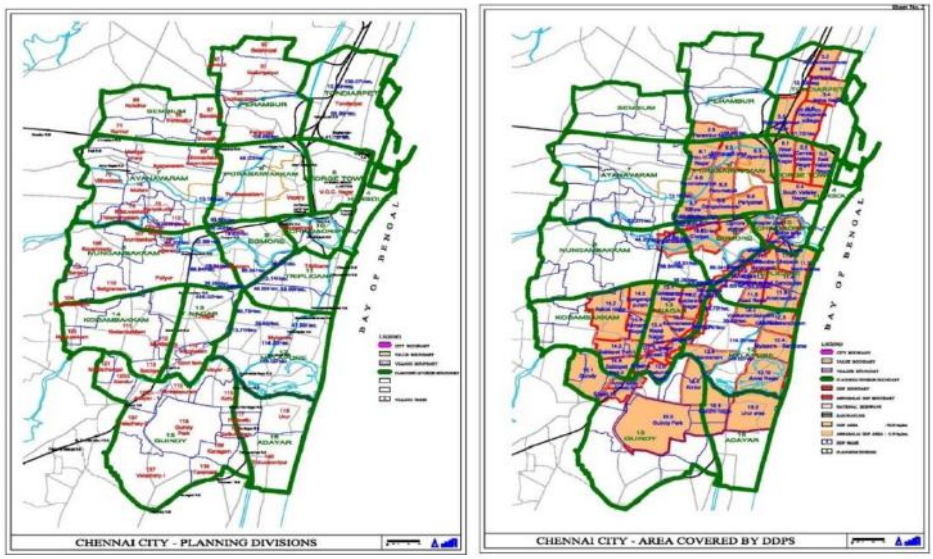

Fig. 2a. Planning Divisions of Chennai City b. Area Covered by DDP's in Chennai City

Source: *Chennai Metropolitan Development Authority*

Second Master Plan for CMA (2008-2026)

The First Master Plan for CMA was prepared in 1975 with the horizon years as 1991. The CMDA initially prepared the Draft Second Master Plan for CMA with the horizon year as 2011 in the year 1995. The Government gave its consent and was submitted to the Government after a public consultation during December 1995. In the meantime, a writ petition was filed in the Hon'ble High Court against the approval of the Second Master Plan and the writ petition was dismissed in 2001. The Second Master Plan for CMA was again resubmitted to the Government by considering the developments undertaken in the urban sector and re-estimating the future requirements for CMA.

The Government, however, returned the Second Master Plan in 2006 with a direction to prepare the plan afresh incorporating further developments in the sector. Accordingly, the Second Master Plan for CMA was prepared with the horizon year as 2026 and was widely consulted through a series of public consultation meetings organized in several locations spread over the entire Metropolitan area to provide equal opportunity to all stakeholders.

The Second Master Plan for CMA was approved by the Government on 2.9.2008 and is in operation from that date. The Second Master Plan considered the various activities that were influencing the urban form of Chennai Metropolitan Development Area including the various road projects under implementation viz, the IT corridor, NH Bye pass and the Outer Ring Road, proposed Metro Rail Projects and the strengthening of suburban Railway infrastructure.

The objectives of the spatial plan as spelt out in the Second Master Plan for Chennai Metropolitan Area are as follows:

1. Optimum utilization of land by channelizing the developments in the right directions and locations.
2. The future land needs of the metropolitan area by recognizing the existing growth trends and strengthening and infrastructure links needed.
3. Efficient transportation network integrating work, living, shopping and recreation areas to arrive at balanced developments.
4. Wider scope for decentralized employment locations and economic development.
5. Preservation and conservation of ecologically sensitive areas and natural and built heritage.

The Second Master Plan is in operation from September 2008. The areas covered by approved Detailed Development Plans were not included in the Second Master Plan for CMA and developments in these areas are regulated based on the land use in the respective Detailed Development Plans.

Grid of Roads

The logical follow up to the Second Master Plan for CMA is to prepare Detailed Development Plans for the remaining areas in the city and the rest of the Metropolitan Area. Detailed Development Plans at the micro-level provides for the required circulation pattern in terms of road widening, missing links, junction improvements, provision for social facilities and other amenities for the resident population. As indicated earlier, the process of preparation of Detailed Development Plans includes the preparation of base maps by defining the area, surveying of existing development and data collection on ownership, preparation of existing land use maps, schedules on the existing land use, ownership and proposed land use, the statement on street alignment, preparation of proposed land use map, consultation with the owners and public and finally obtaining consent from the government. The preparation of Detailed Development Plans was initially considered to be taken up in a phased manner. The average area covered by a Detailed Development Plan is around 1 to 2 sq.km In view of a large number of land parcels, survey and data collection becomes a herculean task and the process of preparation is also time-consuming the focus of the preparation of Detailed Development Plans aims at assigning land use at the micro-level and circulation pattern by way of proposing road widening, geometric improvements etc.

Considering the longer time required for the preparation of Detailed Development Plans and the elaborate process involved in the preparation, CMDA took a policy decision to prepare the Grid of Roads for the fast-growing villages within the Chennai Metropolitan Area as the road network forms the backbone for orderly development and also provides the skeleton for laying trunk infrastructure. Good connectivity improves accessibility and acts as a catalyst in encouraging the population to settle in such areas and paves way for planned development. It was also considered that implementation of Grid of Roads will lead

to the improvement of infrastructure which in turn is one of the major objectives of the Detailed Development Plan. The major tasks that are envisaged in the preparation of Grid of Roads for a given area include identification of existing road network, incorporation of roads in approved layouts, incorporation of already approved link roads, mapping of physical constraints, incorporation of Street Alignment proposed in the Master Plan with the approved Detailed Development Plans, Carrying our site inspection to ascertain the physical condition, working out the hierarchy of Roads, evolving an efficient road network plan providing connectivity and access to major Arterial and Sub-Arterial Roads.

The final report on the preparation of Grid of Roads has been completed for 24 villages located in the southern sector of the Chennai Metropolitan Area wherein new roads and widening of existing roads have been proposed. Adequate precaution has been taken to ensure that no buildings are affected by newly proposed roads with minimum disturbance to the existing buildings. The Grid of Roads has been proposed in such a manner to ensure to provide a walkable distance of 500m for people to reach on Arterial or Sub-Arterial Road to board any form of public transport. The Grid of Roads has been finalized after obtaining the remarks of the Highways Department and the respective Local Bodies. The implementation of the Grid of Roads is to be taken up while processing the applications for planning permission for Buildings and Layouts. The preparation of Grid of Roads is to be taken up in a phased manner for the remaining villages in the Chennai Metropolitan Area.

Land Use/Land Cover Mapping

The impact of the various plans prepared for the Chennai Metropolitan Area is best reflected in the Land Use/Land Cover Mapping of a given area and chronological documentation of the land use/ land cover provides an opportunity to understand the process of development. Hence, an attempt has been made in this paper to monitor the land cover changes that have taken place over Chennai City using multi-temporal satellite images during 1988, 1998, 2008 and 2018. The land use/land cover pattern has been mapped with the use of a supervised classification technique with maximum likelihood algorithm and visual interpretation technique. Land Use/Land Cover classes were classified into five classes namely build-up land, cropland / fallow land, water bodies, Vegetation, and vacant land/scrubland. To identify the physical changes that occurred in and around Chennai city, LULC classification and mapping using multi-temporal satellite images of Landsat for the years 1988, 1998, 2008, and 2018 has been prepared. All the satellite images have a spatial resolution of 30 meters, hence the similarity in spectral and spatial characteristics has compromised.

For visual interpretation, an interpretation key has been prepared based on photo elements such as shape, size, texture, tone, pattern, association, etc. enhanced by ground information reconnaissance survey and Google Earth. The images were classified into five broad land use/ land cover classes namely Built-up land, Cropland /Fallow Land, Waterbodies, Vegetation, Vacant /Scrub Land. The analysis shows that the major changes in the study area are mainly due to the rapid growth in population and industries. From the LULC classified image of 1988 and 2018, it is evident that the build-up area has rapidly increased.

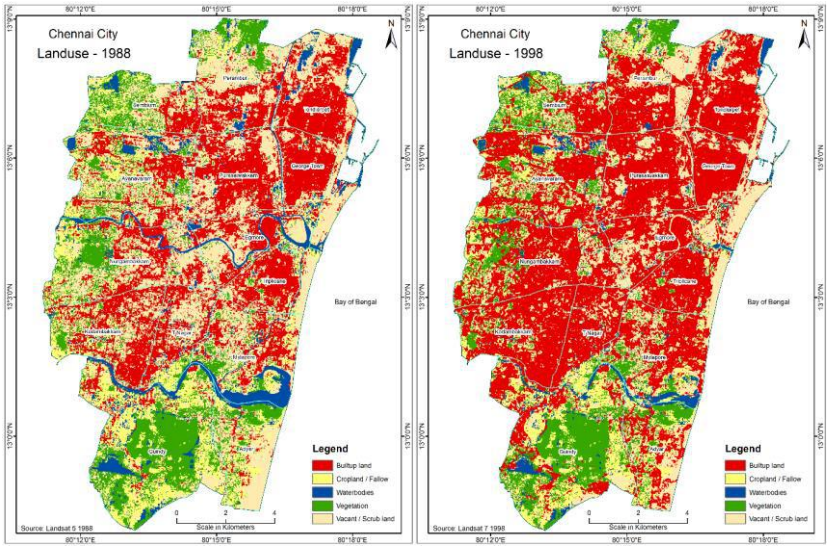

Fig. 3a. Land Use Land Cover Changes: 1988 and 1998

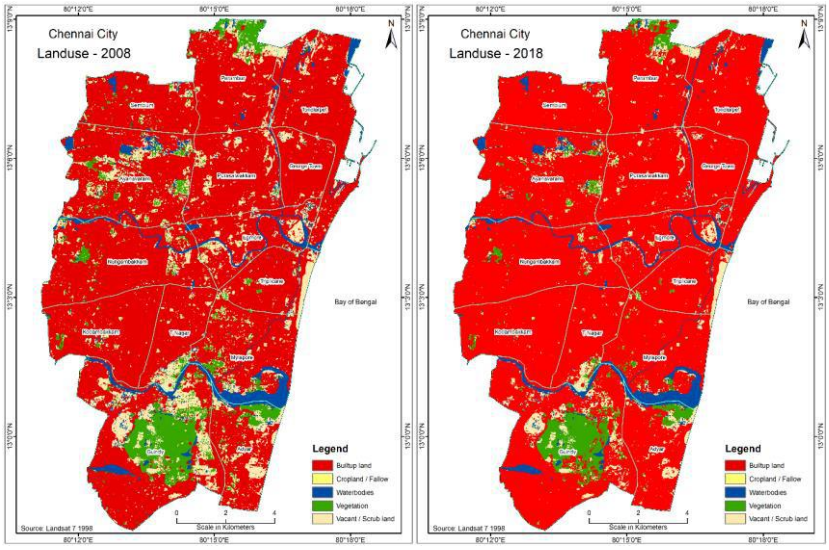

Fig. 3b. Land Use Land Cover Changes: 2008 and 2018

This built-up class shows an indication in the increase of extent in urbanization over the period of thirty years from 1988 to 2018 (Figure 3a and3b), whereas there is a backdrop of changes in Cropland /Fallow Land, Vegetation, Vacant /Scrub Land. The statistical results indicate that the build-up area has compromised human habitation development for non-agricultural uses like buildings, transportation networks have largely broadened from 54.29 km^2 (1988), 85.99 km^2 (1998), 129.23 km^2 (2008) to 148.54 km^2 (2018) with a net addition of 94.25 km^2 between 1988 – 2018. This may be due to urban expansion and the increase of population in the study area during the period. The vacant/scrubland area have largely reduced from 63.12 km^2 1988), 58.76 km^2 (1998),

32.5 km^2 (2008) to 14.35 km^2 (2018). The rate of change has drastically increased between 1998-2008 is 15%, 2008-2018 is 10% and very minor change in 1988 - 1998 is 3%. The analysis reveals that in 1988 the vegetation cover was 27.34 km^2 and it has decreased to 6.04 km^{2}by 2018, which accounts for a decrease of about 21.3 km^2. In 1988, the cropland /fallow land area was 20.02 km2 and it has completely decreased in 2018. Subsequently, the images show that waterbodies occupy 9.48 km^2, 7.31 km^2, 6.2 km^2, and 5.32 km^{2}of total land cover during the years 1988, 1998, 2008 and 2018 respectively. The extent of waterbodies has remained constant over the time periods.

Table 2. Change Detection of Land use/ Land cover (1988 - 2018)

S.No.	Level	1988		1998		2008		2018	
		Area (sq.km)	% Area (sq.km)	Area (sq.km)	% Area (sq.km)	Area (sq.km)	% Area (sq.km)	Area (sq.km)	% Area (sq.km)
1	Built-up land	54.29	31.2	85.99	49.3	129.23	74.2	148.54	85.2
2	Cropland /Fallow Land	20.02	11.5	11.73	6.7	0	0.0	0	0.0
3	Waterbodies	9.48	5.4	7.31	4.2	6.2	3.6	5.32	3.1
4	Vegetation	27.34	15.7	10.46	6.0	6.32	3.6	8.04	4.6
5	Vacant /Scrub Land	63.12	36.2	58.76	33.7	32.5	18.7	12.35	7.1
	Total	**174.25**	**100**	**174.25**	**100**	**174.25**	**100**	**174.25**	**100**

Accuracy Assessment

Remote sensing data can be classified in different ways, notably, only two types of classification techniques are mainly adopted supervised and unsupervised classification. Assessing the accuracy level of the classified image is a vital part of any type of classification techniques adopted. For accuracy assessment 133 samples were randomly selected to assess the accuracy of the classified images using the error matrix technique. It helps to validate the results and the quality of the classification made based on the satellite images. The result provides both class-wise accuracies as well as the overall accuracy of the generated maps.

Table 3. Error Matrices

LULC Class	Built-up land	Cropland / Fallow Land	Water-bodies	Vegetation	Vacant /Scrub Land	Row Total	User Accuracy %
Built-up land	67	3	0	0	5	75	89.3
Cropland / Fallow Land	0	45	4	6	2	57	78.9
Waterbodies	0	2	36	1	0	39	92.3
Vegetation	0	1	0	45	5	51	88.2
Vacant / Scrub Land	4	1	1	3	33	42	78.6
Column Total	71	52	41	55	45	264	
Producer Accuracy %	94.4	86.5	87.8	81.8	73.3		

Overall accuracy = (Total number of correct samples / Total number of samples) x 100
Accuracy Total = (226 / 264) x 100 = 85.61 %

The user's accuracy and the producer's accuracy are the two methods for assessing the accuracy of the land use classes. The producer accuracy evaluates the quality of the classification by calculating the error of emission. The user accuracy evaluates the probability of a pixel belonging to a particular class by calculating the commission error. Another measure for evaluation is the kappa coefficient (K), where the value of kappa varies between 0 and 1. This measure states that the higher the kappa value, the higher the accuracy whereas lower the kappa value, lower the accuracy. The kappa statistics are calculated using the confusion matrix, where row i represents one landuse class and column j represents other landuse class. Diagonal of this i and j matrix shows both the land use map which has the same classes. Finally, for accuracy assessment 226 samples were randomly selected using an error matrix technique. The results derived using the matrix were tabulated and the overall accuracy was calculated as 85.61 per cent whereas the Kappa coefficient calculated for the year was around 82.40%. In the era of advanced GIS and Remote Sensing technologies, the development of any location will be based on LULC changes which will be used for preparing master plans for urban development. This implies that there is a need to incorporate LULC for development of any city planning. Planners across many organizations and industrial sectors will confront the challenge of changing in LULC. It is a mandate to adopt a variety of adaptation practices, designed to plan sustainable urbanization and develop alternative strategies for better management.

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MORPHOMETRIC ANALYSIS OF SATNA RIVER BASIN IN NORTHERN FORELAND OF PENINSULAR INDIA

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Abstract

In the present study, by using the Cartosat-1 DEM data, the morphometric parameters and their interrelationship are estimated and evaluated through the isopleth maps and Pearson correlation matrix. The result revealed that the Satna river basin has 4th to 5th stream orders in five watershed, a high mean bifurcation value for WS3, WS4, and WS5 indicates geological and structural control associated with Upper Vindhyan system. A high and positive correlation of Dd with Fs (r - 0.78), Dt (r - 0.84) and If (r - 0.83) shows that an increase in drainage density helps induces surface runoff over the region, thereby favouring the fluvial erosion of bare rock or topsoil. Further, a high value of RI in WS4 and WS5 indicates maximum rugged terrain that is also linked with steep slope (< 46 degree) at the Bhander escarpment. Thus, the fluvial process could be inferred by the spatial analysis of morphometric parameters in the ArcGIS environment.

Keywords: Cartosat-1 DEM, ArcGIS environment, Isopleth, Morphometric, Upper Vindhyan System

Introduction

Morphometric analysis is the quantitative measurement of the configuration of the earth surface, shape and dimensions of its landforms (Clarke, 1966, Sarkar et. al. 2020). The linear, areal and relief aspect of stream network and basin boundary is considered under the morphometric analysis, which includes the study of various parameters (Hortorn, 1932, Schumn, 1956). The hydrological behaviour of the river basin is revealed by these parameters. A descriptive study and quantification of drainage network under morphometric analysis help to narrate its evolutionary processes since the values of these parameters vary significantly from a flood plain region to a hilly region (Rai et. al., 2017). The initial slope or inconsistencies in rock hardness, structural controls, recent diastrophism, geological and geomorphic history of drainage basin etc. could understand and evaluated by the quantitative assessment of basin geometry because the drainage network of a basin is an integration of all those factors. According to Morisawa (1985), the morphometric characteristics of the drainage basin are important to understand the underlain structure, geomorphological formations and hydrological characteristics. Further, it is useful to resolve different geomorphic problems associated with flood control, soil erosion, landslide,

groundwater potential, construction of groundwater recharge sites, geomorphological process, development of land suitability processes etc. (Strahler, 1952).

Nowadays, in the scientific and satellite era, the geospatial technology has been used significantly for assessing the hydrological behaviour of a basin under morphometric analysis (Mahala, 2019, Carabella, et. al. 2020). Remote sensing is considered to be very effective in providing high-resolution satellite images for understanding the nature of a drainage basin (Sarkar et. al., 2020). The Cartosat-1 DEM (2.5m), SRTM DEM (30m) and ASTER DEM (90m) are the three major remote sensing databases, which accessed globally for extracting synthetic stream layers in ArcGIS environment using the ArcHydro tool (Sangama et. al. 2020). In the present study, Cartosat-1 DEM data have used due to its high spatial resolution. Subsequently, in the 21st century, GIS has been proved a very powerful and promising analytical tool as it can generate, manipulate, store and process the spatial data very efficiently and fast way and to provide high-quality output and efficiently integrate thematic layers for geospatial perspective (Rai et. al. 2017). Various scholars and scientist of the different subject field have successfully applied remote sensing and GIS technique to understand the morphometric characteristics of drainage network and to derive and predict other information like soil loss and hydrological makeup in a mountain environment, flood hazard, land susceptibility etc. Therefore, morphometric analysis in a geospatial environment is a very useful and time-efficient method for proper planning of a river basin unit through efficient utilization of natural resources (Sarkar et al., 2020).

Study Area

The Satna river basin is situated between 24°22'53.167"N to 24°50'23.655"N latitudes and 80°21'40.975"E to 80°52'32.533"E longitudes in the Northwestern part of Satna District in the Madhya Pradesh state of India (Figure 1). Physiographically, it is associated with the upper Vindhyan mountain system, where flat terrain dominates in the middle part of the basin and is a major tributary of the river Tons, it drains northern foreland of Peninsular India. It extends for about 48.90 Km from north to south and 44.12 Km from east to west, covering an area about 1415.86 km^2. The elevation ranges vary from 225 m to 567 m with a slope gradient of 46 degrees at the south-western part of the study region and 0-11 degree at rest part (Figure 5). The river Satna is originated from the north-eastern portion of the basin over the Vindhyan range at an elevation of 420 m, at the geographic coordinate of 24°40'36.39" N and 80°19'40.11"E near the village of Govindpur of Panna district. After covering a distance of about 24.34 km it enters the Satna district having the geographic coordinate of 24°36'59.85"N and 80°27'50.25"E near the Kalpa village and Badhoara village and flows in the middle part of the drainage basin. It meets with the river Tons at the geographic coordinate of 24°30'50.17"N and 80°52'31.21"E near the Ghoti village. The average annual rainfall of the study region is 881.25 mm.

Database and Methodology

Cartosat-1 DEM data of ISRO (year - 2014, tiles - G44U, resolution - 2.5m), downloaded from Bhuvan domain (http://bhuvan-noeda.nrsc.gov.in) was major database for

extracting morphometric layers in the ArcGIS environment by using the ArcHydro tool. The extracted drainage network layer was validated from the Google Earth imagery and toposheet of Survey of India (scale 1: 25,000). Further, the derived layers were associated with Geological map taken from district resource map of Geological Survey of India and the mathematical computation and statistics related to morphometric parameters at the watershed level were calculated in the EXCEL and SPSS software.

First, Satna river basin and all its major tributaries flowing in the Satna district is identified by the deep investigation of the SOI toposheet of Satna district. Raw DEM data is processed in the ArcGIS environment using the ArcHydro tool through generating fill, flow accumulation, flow direction and stream definition layer for delineating the boundary of basin and watershed and generating the stream order network of the study region (Figure 2). However, the accurate delineation of the boundary of the watershed was done by the drainage network layer having a stream threshold value of 100 pixels (Figure 5). Moreover, the stream order layer having stream threshold value of 1000 pixel synchronised with the current drainage pattern is used for estimation of the spatial pattern of areal and relief related morphometric parameters (Figure 5). The isopleth maps showing the spatial distribution of morphometric parameters and terrain characteristics is prepared by applying morphometric formulae at fishnet grid (1 km^2 scale) and IDW interpolation technique is applied on fishnet point (1 km^2 scale) for generating thematic isopleth maps in ArcGIS environment.

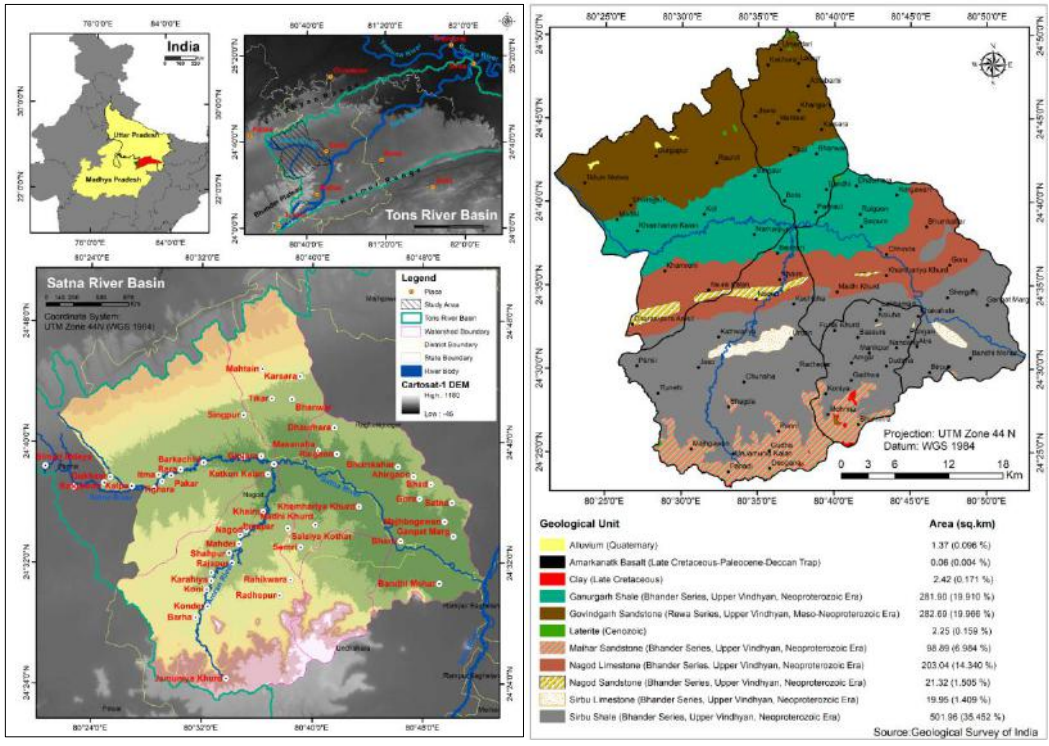

Fig. 1. Location and Geological Structure of the Study Region

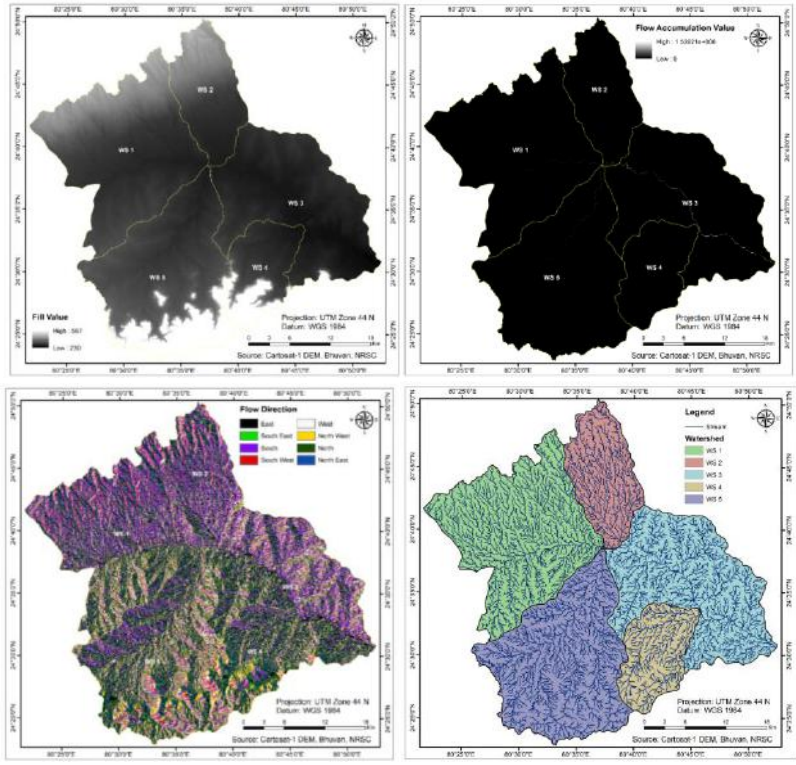

Fig. 2. Methodological layers used to extract drainage network layer: a) Fill Map; b) Flow Accumulation map; c) Flow direction; d) Stream Network Map of Study Area

Results and Discussion

In the present study, five watersheds have been identified and delineated in the Satna river basin. The details of morphometric parameters are discussed in Table 1.

Linear Aspect

The linear aspect of drainage network is analysed in reference with stream order, stream length, stream length ratio and bifurcation ratio. The drainage network is extracted from flow accumulation grid data which is derived by the Cartosat-1 DEM data. Total 1000 pixels covering an area of about 0.871 km2 is considered as flow accumulation threshold for determining synthetic stream grid (Figure 5), in which 5 order streams (Su) has designated in accordance with Strahler`s method (1952) in the study region. Since, a single stream without any tributaries is designated as 1st order stream, the 2nd order stream is produced by joining of 1st order stream, similarly the 3rd order stream develops by the confluence of 2nd order stream, thus in the same fashion lower order streams joins together to form higher-order streams. The whole study region has 5 order streams, in which WS1 & WS2 has designated as 5 order stream networks whereas WS3, WS4 and WS5 are categorised under 4th order stream network.

Table 1. Result of Drainage Network Analysis at Satna River Basin

	Su	Nu	Lu	Lum	Lur	Rb
WS 1	1	122	186.128		1.526	4.067
	2	30	132.415	0.711	4.414	3.333
	3	9	52.726	0.398	5.858	4.500
	4	2	2.631	0.050	1.315	2.000
	5	1	19.419	7.382	19.419	
	Total	**164**	**393.318**	**8.542**	**32.532**	**13.900**
	Average			**2.135**	**6.506**	**3.475**
WS 2	1	39	87.375		2.240	4.875
	2	8	54.801	0.627	6.850	2.667
	3	3	18.274	0.333	6.091	3.000
	4	1	3.344	0.183	3.344	1.000
	5	1	3.712	1.110	3.712	
	Total	**52**	**167.507**	**2.254**	**22.238**	**11.542**
	Average			**0.563**	**4.448**	**2.885**
WS 3	1	114	157.827		1.384	4.222
	2	27	64.032	0.406	2.372	4.500
	3	6	37.075	0.579	6.179	6.000
	4	1	34.501	0.931	34.501	
	Total	**148**	**293.435**	**1.915**	**44.436**	**14.722**
	Average			**0.958**	**22.218**	**4.907**
WS 4	1	45	47.631		1.058	6.429
	2	7	25.511	0.536	3.644	2.333
	3	3	31.930	1.252	10.643	3.000
	4	1	1.189	0.037	1.189	
	Total	**56**	**106.260**	**1.824**	**16.535**	**11.762**
	Average			**0.912**	**8.267**	**3.921**
WS 5	1	132	152.793		1.158	4.400
	2	30	70.288	0.460	2.343	4.286
	3	7	64.405	0.916	9.201	7.000
	4	1	25.905	0.402	25.905	
	Total	**170**	**313.392**	**1.779**	**38.607**	**15.686**
	Average			**0.889**	**19.303**	**5.229**
Satan River Basin	1	452	631.754		1.398	4.431
	2	102	347.047	0.549	3.402	3.643
	3	28	204.4094	0.589	7.300	5.600
	4	5	70.093	0.343	14.019	5.000
	5	1	19.419	0.277	19.419	
	Total	**588**	**1272.723**	**1.758**	**45.538**	**18.674**
	Average			**0.440**	**9.108**	**4.669**

***Abbreviations**: S_u-Stream Order; N_u-No. of Stream; L_u-Stream Length in km; L_{um}- Mean Stream Length in km; L_{ur}-Stream Length Ratio; R_b-Bifurcation Ratio*

The frequency of a stream segment exists in a certain order (Horton, 1945) is studied under stream number (Nu) which reveals geomorphic characteristics of the studied basin; since the number of stream segment of different order decreased with increase in stream order (Horton, 1932, Harsha et. al, 2020). The different order stream number in the study region reveals that 1st stream order possesses the highest number of stream segments as the WS1, WS2, WS3, WS4, and WS5 have 122, 39, 114, 45 and 132 number of streams respectively, whereas highest order stream (either 4th order or 5th order stream) have only a stream. This pattern of drainage network indicates erosional dominance over the topography in the study region. Total stream length (Lu) of Satna river basin is 1272.72 km, in which river Satna constitutes 71.501 km, flowing in the south-eastern direction of the study region dominated in the WS3. While the major tributary of river Satna is river Amran

which flows in the WS5 with south-western direction and constitutes about 51.42 km. Generally, an inverse relationship exists between successive stream order and total stream length i.e. 1st order stream have 631.75 km length, 2nd order stream have 347.05 km length, 3rd order stream have 204.41 km length, 4th order stream have 70.09 km length and 5th order stream have 19.42 km length. The stream length ratio (Lur) is the ratio of mean length of a certain stream order to mean length of next lower stream order, which expressed (Strahler, 1964) as;

$$〖\text{Stream Length Ratio,L}〗_{ur} = L_u / L_{(u-1)} \quad (1)$$

where Lu is total stream length of a given order; and Lu-1 is total stream length of next lower order.

The Lur of Satna river basin is 1.758, while it is 0.549, 0.589, 0.343 and 0.277 for 1^{st}-2^{nd} order, 2^{nd}-3rd order, 3^{rd}-4^{th} order and 4^{th}- 5^{th} order stream respectively. On contrary to stream length (Lu), a positive relationship exists between successive stream order and mean stream length ratio (Lurm), which is also seen in the Satna river basin. The Lurm of Satna river basin is 45.54, while it is 1.398, 3.402, 7.300, 14.019 and 19.419 for 1st order, 2nd order, 3rd order, 4th order and 5th order stream respectively. The change in Lurm from 1.39 to 19.42 is attributed to variations in the topography and slope gradient. Moreover, the youth and mature stage of geomorphic development of 1^{st}-2^{nd} order and 4^{th}-5^{th} order stream respectively is revealed by this ratio.

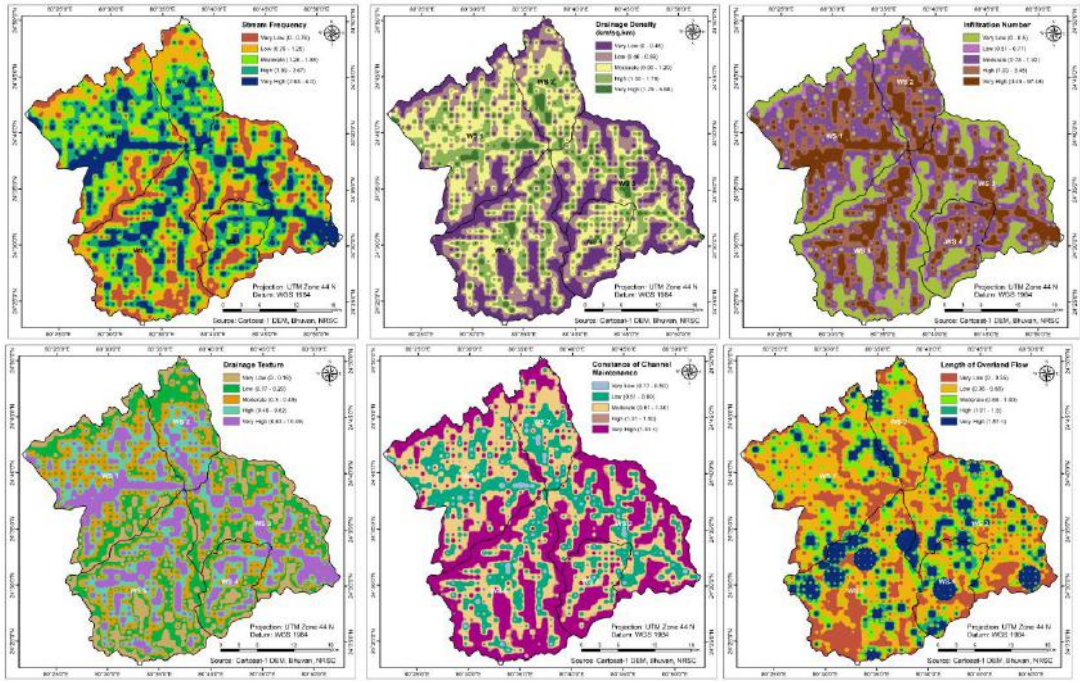

Fig. 3. Areal Morphometric Parameters of Study Area

In contrast to Lur, bifurcation ratio (Rb) is the numbers of streams of a particular order (Nu) to the number of streams of higher orders (Nu +1) (Strahler, 1964);

〖Bifurcation Ratio,R〗 _b= N_u/N_(u+1) (2)

The total Rb value for the whole study region is 18.64, while the mean Rb value of the study region is 4.67 (Table 1. At the watershed level, the mean Rb value shows variation from 2.89 to 5.23. Since the Rb value, less than 3 indicate almost flat terrain without any structural control on the drainage system. However, a higher value of Rb like 3 to 5, indicates that the geological structure has less influence on the drainage pattern. Rb value exceeds 5 indicates geological structural control on the pattern of drainage network as it distorts the streamflow. In the study region, WS5 and WS3 have the highest value of Rb 5.23 and 4.91 respectively, whereas WS2 have the lowest value of Rb 2.89 followed by WS1 (3.48) and WS4 (3.92).

Drainage Texture Analysis

Various areal parameters viz.; stream frequency, drainage density, infiltration number, drainage texture, constant of channel maintenance and length of overland flow are considered under the drainage texture analysis. A detailed analysis of theses parameters is useful to find out the amount of dissection in the geomorphic structure.

Table 2. Watershed Wise Comparison of Areal, Geometric and Relief Parametres in Study Region

Morphometric Parameters	WS 1	WS 2	WS 3	WS 4	WS 5	Study Area
Area (km^2)	393.29	154.67	348.63	127.44	383.84	1415.857
Perimeter (km)	139.52	73.13	134.65	64.54	125	212.09
Basin Length (km)	32.581	21.499	29.207	17.685	30.029	55.809
Drainage Density (D_d)	3.357	3.563	2.995	2.658	3.496	3.214
Stream Frequency (F_s)	2.330	2.380	1.978	2.230	2.570	2.298
Infiltration Number (I_f)	3.619	3.533	2.932	3.192	4.025	3.460
Drainage Texture (D_t)	0.574	0.559	0.484	0.557	0.642	0.563
Constant of Channel Maintenance (C)	1.864	1.561	1.890	2.445	1.954	1.943
Length of Overland Flow (L_g)	0.932	0.780	0.945	1.222	0.977	0.971
Elongation Ratio	0.686	0.652	0.721	0.72	0.736	0.761
Form Factor Ratio	0.370	0.335	0.409	0.407	0.426	0.455
Circularity Ratio	0.254	0.364	0.242	0.385	0.309	0.396
Height of Basin Mouth(z)	400	416	492	567	535	567
Maximum Height of the Basin (Z)	248	246	225	240	248	225
Total Basin Relief (H)	152	170	267	327	287	342
Relief Ratio (R_h)	4.665	7.907	9.142	18.49	9.558	6.128
Ruggedness Number (R_n)	0.151	0.183	0.223	0.271	0.233	0.308
Dissection Index (D_{is})	0.38	0.409	0.543	0.577	0.536	0.603
Ruggedness Index (R_I)	3.426	3.319	3.795	6.706	5.293	4.507
Maximum Elevation	400	416	492	567	535	567
Mean Elevation	324	331	358.99	402.545	390.507	395.538
Slope	1.581	1.553	1.859	4.064	2.969	2.224

Stream frequency (Fs) is the ratio between the total number of stream segment (Nu) cumulative of all orders and the basin area (A) (Hortorn, 1932). The relief, slope gradient, rainfall, and resistivity of the rocks impact upon the Fs, therefore it gives idea

about the permeability and infiltration capacity of the basin. The high value of Fs indicates more surface runoff compared to infiltration that is characteristics of a mountainous region having steep slope gradient, while the lower value indicates low surface runoff. The value of Fs for Satna river basin is 2.298, while it has a slight difference among all five watersheds. The WS3 has the lowest value (2.002) of Fs, which indicates low surface runoff and high infiltration capacity of the watershed. Whereas, the WS5 has the highest value (2.57) of Fs, closely followed by WS2 (2.38) and WS1 (2.33).

In contrast to this, the spacing of streams and its interaction with geology is defined as drainage density (Dd) which is a measure of total stream length over the total area in a given basin (Strahler, 1964). Watersheds having high drainage densities denote increased closeness in the spacing of channels which lead to a greater amount of surface runoff than infiltration, thus it indicates the impervious structure of terrain that possess low erodible surface materials (Ghosh and Paul, 2019, Singh et. al., 2020). Whereas the low value of Dd indicates fairness in the spacing of channels and resistant surface material. The Dd for the Satna river basin is 3.21 km-1. In the study region, WS2 have the highest value of Dd (3.56 km-1.) followed by WS5 with 3.49 km-1. Whereas, WS4 have the lowest value of Dd (2.66 km-1), followed by WS3 (2.99 km-1) and WS1 (3.37 km-1) having a slightly high value of Dd compared to WS4. Since the higher value of Dd in WS2, WS5 and WS1 are attributed to the presence of sandstone (Govindgarh or Maihar sandstone) and Ganurgarh shale which are hard, compact and impervious in nature, found in the northern fringe of Satna river basin (Figure 5).

A function of drainage density (Dd) and stream frequency (Fs) is defined as the infiltration number (Faniran, 1968), which not only indicates the rate of infiltration i.e. process by which water on the ground surface enters the soil but also explains hidden characteristics of the terrain and its pedologic environment. The value of If for Satna river basin is 3.46. The WS5 (4.03), has the highest value of If followed by WS1 (3.62) and WS2 (3.53), which indicates high surface runoff and low infiltration capacity of the watershed since this region have a dominance of hard and compact rocks (shale, sandstone and quartzite etc.) over the surface with a steep slope gradient at the hilly region, which does not allow the surface water to penetrate into deep rock layers. While the WS3 (2.93) has the lowest value of If, it indicates high infiltration capacity of the watershed compared to other, which is also linked with permeable limestone lithology of the region (Figure 5).

The relative spacing of streams is studied under the drainage texture (Dt), that is a total number of streams segments of all orders in a river basin to the perimeter of the basin (Horton, 1945). The underlying lithology and relief are major factors that impact on the Dt of the basin. In the study region, computed value for Dt is 0.563, it explains that Satna basin has a very coarse texture. Although all five watersheds are categorised under very coarse texture of the drainage basin as the Dt value is less than 1.0. Still, drainage texture of WS5 is coarser (0.642) in nature compared to WS2 (0.484). Length of overland flow (Lg) is half of the ratio derived by the total length of stream (Lu) of a basin to its total area (A). It is the length of the flow of water over the ground before it becomes concentrated to definite stream channels.

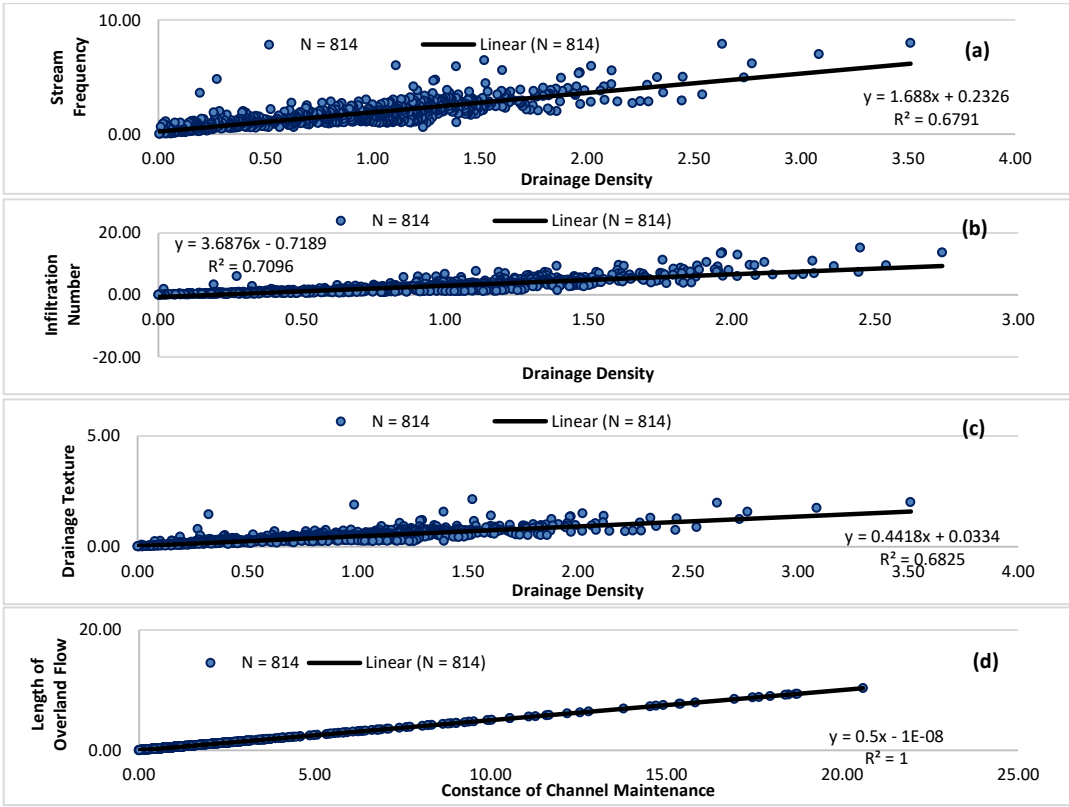

Fig. 4. Linear regression observed at 814 random points between (a) drainage density and stream frequency; (b) drainage density and infiltration number; (c) drainage density and drainage texture (d) length of overland flow and Constance of channel maintenance

Horton (1945) has expressed the formula of Lg as;

$$\text{Length of overland flow, } Lg = 1/2 * A/(\sum Lu) \quad (3)$$

The computed Lg value for the entire study region is 0.971. WS2 has the lowest value of Lg, which is 0.78, whereas WS4 (1.22) records the highest value of Lg. While the other remaining watershed has a slight difference in the value of Lg i.e.WS5 (0.98), WS3 (0.91) and WS1 (0.93). Since, the higher value of Lg indicates the gentle slope of the terrain, longer concentration-time and high degree of sheet erosion if the underlying rock is not much resistant to sheet erosion. In the study region, the main tributaries of all watersheds are distributed over the region, where relief varies from 225 m to 303 m with a slope of 0 to 5.70 degree. Since almost 51.47 % geographical area of WS2 is distributed within this region; hence the lower value of Lg could be attributed to relatively high relief of this watershed. While, 53.14 %, 63.23 %, and 99.39 % geographical area of WS5, WS4 and WS3 respectively fall within this relief (225m - 303m) zone. Hence these watersheds recorded relatively high value of Lg, which determines hydrological and physiographic development of the basin.

Constant of channel maintenance is a ratio, which is reciprocal of drainage density; it is used to define that minimum area required for the development and sustentation of a channel in a basin (Schumn, 1956). The value of C for the entire study region is 1.94km^2/km, which denotes that 1.94 km^2 area is required for sustenance of a kilometre of stream channel in Satna river basin. Since the WS4 (2.44) and WS5 (1.95) belongs to mountain ecology characterised with higher relief, steep slope and high overland flow, so it tends to have higher value of C which also indicates lower flood potentiality as almost 0.88 $km^2$and 0.39 km^2 area would be more required for flood potentiality as compared to WS2.

Interrelationship between Areal Aspects of Morphometric Parameters

Since all the morphometric parameters are interrelated hence a correlation matrix is generated for computing the interrelationship between areal-morphometric parameters and to infer the fluvial processes which are linked with the surface runoff and infiltration capacity of the study region. A significant correlation ($p < 0.05$) is recorded between areal-morphometric parameters, obtained from the 814 random points (Table 3 and Figure 4). Fs, Dt and If correlated positively with Dd with correlation coefficient values (r) of 0.787, 0.839 and, 0.833 respectively. This result shows that an increase in drainage density helps induces surface runoff over the region, thereby favouring the fluvial erosion of bare rock or topsoil. C has shown to correlate perfectly positively with lg ($r = 1.0$) suggesting that the region high in C tend to favour the high flow path of surface runoff. Dt-Sf and Dt-If are also shown to correlate positively with one another suggesting that when the texture of drainage is increased, it increases the stream frequency and surface runoff, thus rendering it available for erosional work through the fluvial process. Therefore, the correlation matrix showed that there is a great interaction among these parameters in the study region, a strong correlation between two parameters may be an occurrence of both parameters on the same casual factor probably due to slope gradient and underlying lithological impact.

Basin Geometry

The underlying geological structure, lithology, relief and precipitation pattern of study area impact on three parameters viz.; elongation ratio, form factor ratio and circulatory ratio which are used for the quantitative expression of shape of the basin that varies from narrower elongated form to circular form. Elongation ratio (Re) is the ratio between the diameter of the circle having the same area as the basin and maximum length of the basin (Lb) measured along the direction of principal drainage line (Schumn, 1956). It is expressed as follows;

〖Elongation Ratio,R〗 _e=2/L_b *(A/π)^0.5 (4)

Its value varies from 0 (maximum elongated) to near 1 (maximum circularity). Different shapes of basin are identified through the elongation ratio i.e. more elongated (< 0.5), elongated (0.5 – 0.7), less elongated (0.7 – 0.8), oval (0.8 – 0.9) and circular (> 0.9). The Re value for Satna river basin is 0.76, which is classified under a less elongated shape of the basin. However, WS1 and WS2 have an elongated shape as the Re value is 0.69 and 0.66 respectively.

Whether WS3, WS4 and WS5 all have a less elongated shape as their Re value are 0.72, 0.72 and 0.74 respectively. The elongated or less elongated shape of the watershed is also visibly validated in Figure 5. Since the Re value not only indicates the shape of the basin but it also correlates the shape with denudational characteristics and gives the idea about hydrological behaviour. The lower value of elongation ratio indicates active denudational process with high infiltration capacity and low surface run-off in the basin, whereas higher Re values indicate the higher elevation of the basin susceptible to high headward erosion along tectonic lineaments, but characterized with high peak flow in short duration (Strahler, 1964). While in the form factor (Rf) ratio the squared value of the basin length is considered as described by Horton, (1932);

〖Form Factor Ratio,R〗_f=A/〖L_b〗^2 (5)

The value of Rf should not exceed 0.785, which indicates the perfect circular shape of the basin, while the Rf value near 0 to 0.54 implies the elongated shape of a basin. Since like the Re value, the higher value of Rf experience larger peak flows of shorter duration which is the characteristics of drainage basin lying in the mountainous region, while the basin having a lower value of Rf which indicates the elongated shape of the basin, it is the characteristics of drainage basin lying in the plain region having very gentle slope experience lower peak flows of longer duration (Gregory and Walling, 1985). The Rf value for Satna river basin is 0.455, while it is 0.372, 0.337, 0.411, 0.410 and 0.428 for WS1, WS2, WS3, WS4 and WS5 respectively. Therefore, an elongated shape of Satna river basin and all it`s watershed is revealed by the lower value of Rf, which not exceeds than 0.54 in all watershed, thus a moderate peak of flow for neither very long nor very small duration is inferred in the study region which is a mountain- plateau front river basin. This phenomenon also suggests that WS3, WS4 and WS5 are still influenced by geological processes and tectonic activities compared to WS1 and WS2. In contrast to both ratios; the Circularity ratio (Rc) considers the area of a circle having the same perimeter as the basin (Strahler 1964) which expressed as follows:

〖Circulatory Ratio,R〗_c=4πA/P^2 (6)

Similar to Re and Rf, the value of Rc close to unity indicates a circular shape of the watershed while the value close to 0 indicates the perfect elongated shape of a basin. Since, the area and perimeter are considered for the calculation of Rc, although practically it is influenced by climate, length and frequency of stream, lithology and structure of the soil, nature of relief and slope, characteristics of land use/land cover etc. The Rc value for Satna river basin is 0.396, while it is 0.410, 0.558, 0.383, 0.612 and 0.491 for WS1, WS2, WS3, WS4 and WS5 respectively. Thus an elongated shape of all watershed is inferred from Rc well.

Relief Parameter

The relative relief, shape and length of the mainstream, slope and nature of the underlying rocks are primary factors affecting the value of relief ratio (Rr), so the value of Rr

becomes high in the region which has mountain ecology compared to the plain environment of the terrain. The Rr is derived by dividing the total relief of the basin (H) to the maximum length of the basin in accordance to principal drainage line of the basin (Lb) (Schumn, 1956) expressed as follows;

〖Relief Ratio,R〗 _r=H/L_b (7)

Hence, the steepness of the watershed and related degradation process are also explicit by this parameter (Schumm 1956). The computed Rr value for Satna river basin is 6.128, which is quite high and it explains the lower denudation stage of geomorphic evolution. WS 4 has the highest value of Rr 18.490, which falls under the very high category of Rr, whereas WS 1 has the lowest value of Rr 4.67, which falls under the moderate category of relief ratio. If the Lb is replaced with absolute relief (Ra) in the formula (7), dissection index (Dis) is derived which reveals the stage of geomorphic development of the basin as it indicates vertical erosion and dissection in the region. Its value varies from 0 to 1, if the value of Dis is near to zero, it indicates maximum denudation of geomorphic development which indirectly explains the characteristics of flat terrain and plain region, while the value near to 1 represents minimum denudation in case of the vertical region i.e. mountainous region. For the study region, the value of Dis ranges from 0.380 for WS1 to 0.577 for WS4, and for Satna river basin the value of Dis is 0.603. It shows that the whole study region falls under the moderate category of dissection, while the WS1 and WS2 have more dissection compared to WS3, WS4 and WS5. Although if we consider, a different parameter like ruggedness number (Rn) for analyzing the stage of denudation and dissection of the basin, then it also shows that WS4 has more dissection than WS1. Since the Rn also considers the fluvial process for analyzing dissection of the region as it is the product of relative relief and drainage density; hence it better describes the vertical erosion (Strahler, 1964);

〖Ruggedness number,R〗 _(n)=D_d* (H/1000) (8)

The value of Rn for the Satna river basin is 0.308 and it is relatively lower 0.271, 0.233, 0.223, 0.183, and 0.151 for WS4, WS5, WS3, WS2 and WS1 respectively. The result of Rn value for Satna river basin through Strahler`s formula is also correlated with the result of the ruggedness index (RI) layer derived from Cartosat-1 DEM data in the inbuilt environment of QGIS. Table 4 showed that Rn and RI both are significantly correlated on linear regression model (F= 128.045 > 0.0077, t = 11.316> 2.353, R2 = 0.98 %, R = 0.988), thus it signifies both techniques for analysing vertical dissection in the Satna river basin.

Table 4. Pearson Correlation Coefficient Matrix between Relief Morphometric Parameters of Satna River Basin

	R_r	R_n	D_{is}	R_I	Slope
R_r	1.00				
R_n	0.41	1.000			
D_{is}	0.48	0.951	1.000		
R_I	0.86	0.641	0.676	1.00	
Slope	0.89	0.588	0.632	0.99	1.000

** Correlation is significant at the 0.05 level (2-tailed), N = 5*

***Abbreviations**; R_r-relief ratio; R_n-ruggdness number; R_I- ruggdeness index; D_{is}-dissection index*

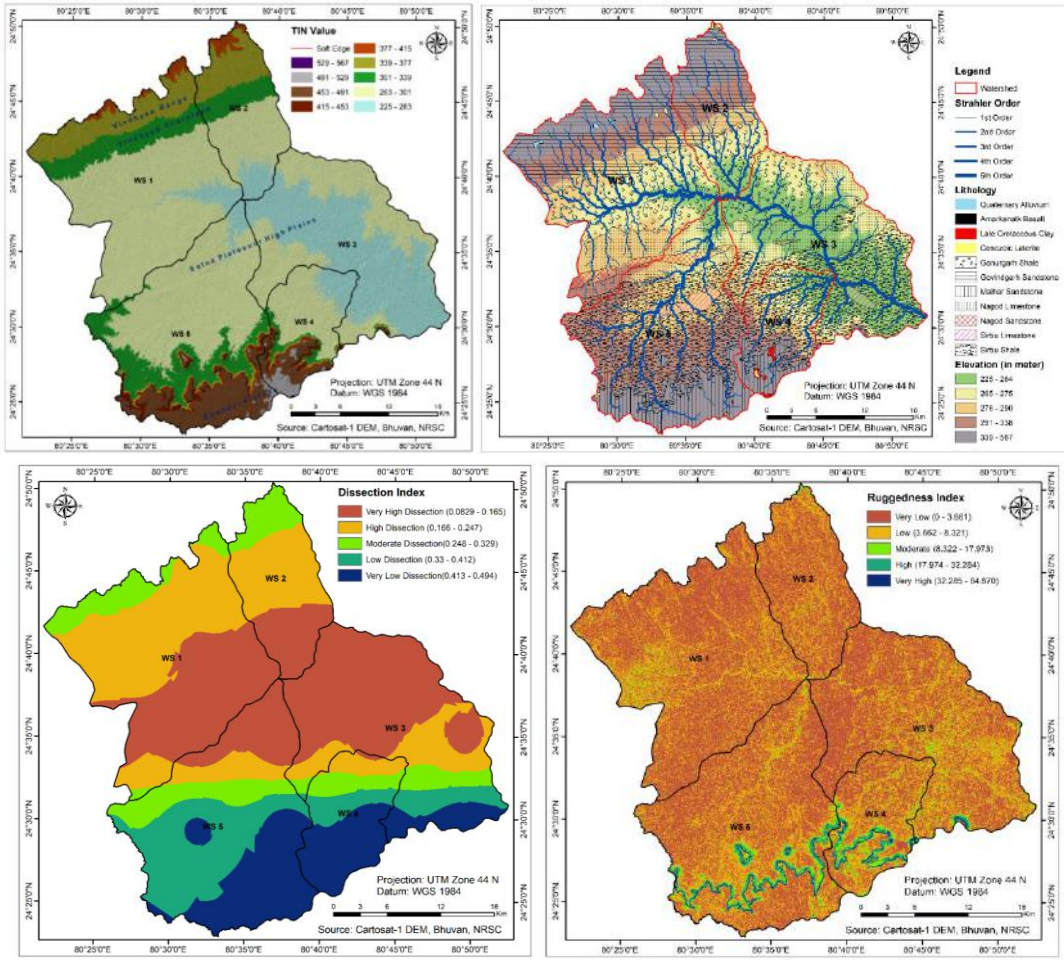

Fig. 5. Physiographic, Drainage Network, Dissection Index and Ruggedness Index of the Study Region

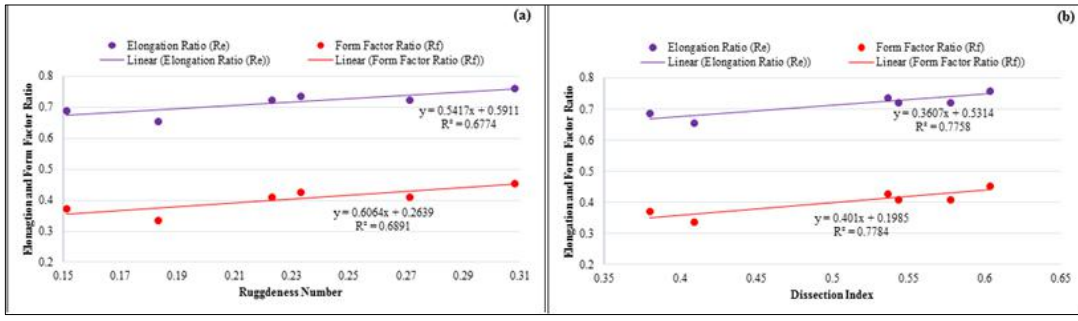

Fig. 6. Linear Regression of Elongation Ratio and Form Factor Ratio with (a) Ruggedness Number; (b) Dissection Index Observed at the Watershed Level

The RI statistics shows that WS4 and WS5 have maximum rugged terrain, as the maximum RI is 73.70 with a mean and sd value of 6.71 and sd 7.99 respectively for WS4. It is 84. 87 for WS5 with a mean and sd value of 5.29 and sd 6.81 respectively. The primary factor for the ruggedness in the Satna river basin is determined by the nature of rock and slope. Since the south-western part of Satna, the river basin is characterized with a steep slope (< 80 degrees) where WS4 and WS5 are distributed. In order to find out the impact of slope on vertical erosion through the fluvial process, the mean value of RI and slope is correlated on the linear regression model. Result showed that 99.88 % ruggedness of the watershed is attributed to slope in all watershed (F= 128.045 > 0.0077, t = 11.316> 2.353, R2 = 0.98 %, R = 0.988).

Validation of Basin Shape through Rn and Dis Index

The visual examination of Figure 5 shows that Satna river basin and its entire watershed have an almost elongated shape, although the areal indices estimated for the basin objectively confirm this assessment as well. However, in the present study, the value of Re, Rf and Rc is correlated with the value of Rn and Dis index on the linear regression model, in order to validate the result of morphometric analysis and for accurately validating and inferring the geomorphological behaviour of each watershed of Satna river basin. Figure 6 showed that Re and Rn both are significantly correlated on linear regression model (F= 8.40 > 0.044, t = 2.89> 0.044, R2 = 0.677 %, R = 0.823), also the value of Rf is correlated with Rn (F= 8.87 > 0.041, t = 2.98> 0.041, R2 = 0.69 %, R = 0.83). Moreover, the value of Dis is also correlated with Re (F= 13.85 > 0.020, t = 3.72> 0.020, R2 = 0.78 %, R = 0.88) and Rf (F= 14.05 > 0.020, t = 3.75> 0.020, R2 = 0.78 %, R = 0.88) on linear regression model, thus it signifies both techniques for analyzing vertical dissection in the Satna river basin. The value of Re, and Rf both are high in the WS3, WS4 and WS5, it indicates that the influences of tectonics within the watershed which is also proved by the high value of Rn and Dis in those watersheds, while the rest of the watersheds such as WS1 and WS2 has least influenced by tectonic processes since it has a low value of Re, Rf, Rn and Dis as well. Also, the high, medium and low value of Re, Rf, and Rc are indicative of young, mature and old stages of geomorphological adjustment of any basin, therefore in the study region, almost the medium value of all three geometric parameters suggest the mature stage of geomorphological adjustment, which is not only validated by the value of ruggedness index and dissection index but on-field it has observed that mountain–plateau front river basin forms an elongated shape in response to the mature morphological adjustment.

Conclusion

Thus, it could be concluded that the descriptive study and analysis of morphometric parameters in Satna river basin at the watershed and spatial level reveals underlying structural control of Upper Vindhyan system on flowing of streams and indicates manifold hydrological dynamics. The estimation of morphometric parameters in the geospatial environment is also prior for understanding the hydrological conditions of the basin and interpreting flood-prone channels, fluvial process related to erosion and deposition, soil

erosion modelling, groundwater exploring, resolving water scarcity problems in long term etc. In the present study, the morphometric parameters are not only estimated at watershed level but their correlation with each other is also modelled using the linear regression method in order to predict their stage of geomorphic evolution and associated vertical dissection. Since all the morphometric parameters are interrelated hence a correlation matrix is generated for computing the interrelationship between areal-morphometric parameters and to infer the fluvial processes which are linked with the surface runoff and infiltration capacity of the study region. A significant correlation ($p < 0.05$) is recorded between areal-morphometric parameters, obtained from the 814 random points. A high and positive correlation of Fs, Dt and If with Dd indicates that an increase in drainage density helps induces surface runoff over the region, thereby favouring the fluvial erosion of bare rock or topsoil. C has shown to correlate perfectly positively with lg ($r = 1.0$) suggesting that the region high in C tend to favour the high flow path of surface runoff. Dt-Sf and Dt-If are also shown to correlate positively with one another suggesting that when the texture of drainage is increased, it increases the stream frequency and surface runoff, thus rendering it available for erosional work through the fluvial process. Therefore, the value and spatial distribution of all these areal morphometric parameters indicate that surface runoff is high across the Bhander plateau, Vindhyan range and Vindhyan scarp land region. It is further validated by the high value of Dis and Rn in that region. While the high plains of Satna river basin have a lower impact of vertical dissection due to flat terrain and low surface runoff, hence a thin layer of soil is found in this region.

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AUTOMATED SURFACE WATER EXTRACTION USING DIFFERENT SPECTRAL INDICES FROM THE SATELLITE IMAGE FOR ERNAKULAM DISTRICT

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Abstract

Water is an indispensable part of ecosystems and valuable, substantial reserves for social survival and human development. Remote sensing has been successfully applied as it facilitates to harness the natural resources effectively. The present study has been carried out in the Ernakulam District of Kerala to detect waterbodies and determine the surface area changes of waterbodies from 1991 to 2019. Remote sensing techniques have been used as an essential tool for understanding spatial changes. The change in surface waterbodies can be identified using these techniques. The Normalized Difference Water Index (NDWI), Modified Normalized Difference Water Index (MNDWI), Automated Water Extraction Index (AWEI), and Water Index 2015 (WI2015) were developed for the detection of water features from Landsat imagery. These indices were used to identify waterbodies of Ernakulam District. This study provides a scientific way to understand waterbodies using remote sensing techniques.

Keywords: Automated surface water extraction, Remote sensing, Indices, Waterbodies

Introduction

Water stabilizes ecosystems and maintains climate variation, carbon cycling, and so on. Hence, its accurate and automatic extraction is a challenge. Remote sensing technology is widely used for detecting changes. It is used for different purposes, such as land use/cover change, disaster monitoring, forest and vegetation change, urban sprawl, and hydrology. Remote sensing data is generally applied to these studies. Observing changes using remote sensing is extensively used in various applications such as land use/ land cover changes, disaster monitoring, forest and vegetation change, urban sprawl, and hydrology. Trustworthy knowledge about surface water's spatial allocation is critically significant in numerous scientific methods such as estimating present and future water resources, wetland inventory, watershed study, surface water examination and management, flood mapping, and environment monitoring (Desmet, 1996). Remote sensing satellites at various spatial, spectral, and temporal resolutions give an enormous volume of data that have become prime sources, mainly used to detect and extract surface water and its changes in recent decades. The Normalized Difference Water Index (NDWI), Modified

Normalized Difference Water Index (MNDWI), Automated Water Extraction Index (AWEI) was generated for the extraction of water features from Landsat imagery.

Remote sensing satellites at different spatial, spectral, and temporal resolutions give an immense quantity of data that have become primary sources, and it is mainly used for identifying and extracting surface water and its changes in recent decades (Xu, 2006). This study contributes a precise way to know about the waterbodies by using remote sensing techniques. Hence it would be useful for the decision-making process and help administrators and experts formulate suitable plans for sustainable water resource management. The paper focuses on the current condition of the waterbodies of Ernakulum district due to the accelerated expansion in urbanization and to evaluate the reduction of waterbodies using landuse and land cover and water indices methods from 1992 to 2019.

Study Area

The study is in Ernakulam District, Kerala to identify waterbodies and to analyse the waterbodies' surface area changes from 1991 to 2019. It holds an area of 2407 sq.km. It is bordered in the west by the Arabian Sea, in the north by Thrissur and Alappuzha, Kottayam districts in the south, Idukki District in the east. The district is well joined with a sound system of roads and railways. One of the rapidly growing city Cochin is located in this district. The accelerated urban extension around Cochin results in the invasion of water resources. In this situation, the demand for research about the waterbodies and their surface area variations is essential. The total area of Ernakulam District is 2407 sq.km. One of the growing port city, cochin is the headquarters of the district. The district has a great system of roads and railways. The longest flowing river Periyar is flowing through this area.

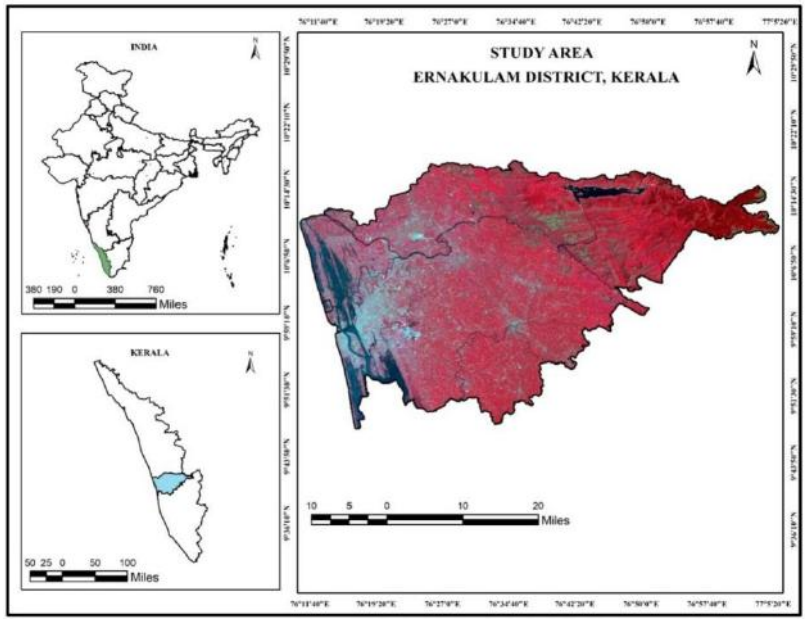

Fig. 1. Ernakulam District, Kerala

Database and Methodology

The study was carried out using Landsat 4-5 TM for 1992(on 6 March) and Landsat 8 for 2019(on 23 March). These data are collected from the United States Geological Survey (USGS). The satellite data downloaded from the USGS earth explorer is pre-processed in Erdas Imagine. Supervised classification and Change detection techniques were used to find out landuse change. Indices like NDWI, AWEI, MNDWI techniques were used to extract waterbodies from satellite images.

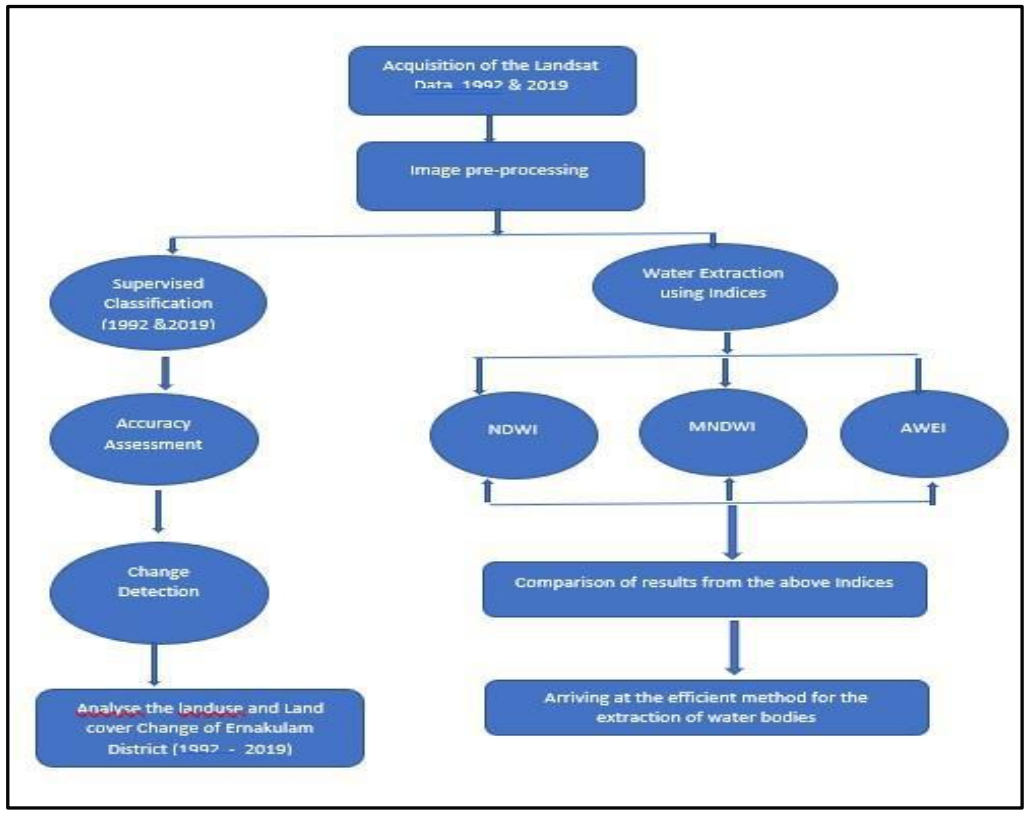

Fig. 2. Methodology of the Study

Results and Discussion

Landuse and Land cover

Application of land use /land cover changes helps plan and manage an area, as up-to-date knowledge is needed to understand the prevailing area of land and its land cover and identify land-use changes from year to year. This understanding will help in conservation, diverse practices, and developmental pressures. Land cover is the physical element at the surface of the earth. Land covers include grass, asphalt, trees, bare ground, water, etc. In 1992, the area was having a considerable amount of water resources. The settlements are found around Cochin, which is a coastal belt. Aluva and Vypen have high settlements in the year 1992. The total built-up area accounts for about 12,500 hectares.

Nearly 150,000 hectares are under agricultural land, which includes plantation crops and paddy fields. Forest areas cover around 72,000 hectares, which is located in the eastern part. Barren lands occupy nearly 53,000 hectares. In 2019, waterbodies were reduced. Many small waterbodies, which were present in 1992 were missing in the 2019 map. Built-up land covers the areas near the coastal belt, and barren lands have turned into residential areas. Built-up areas cover nearly 55,000 hectares of land. Cochin international airport, which is built in 1994, is located near a tank. Agriculture area has been lessened due to human intrusions, and many farming areas are converted into built-up land. Nearly 125,000 hectares of land was covered by agriculture in 2019. Forest land was reduced from 1992 due to deforestation activity. Barren land has reduced from 1992 to 2019; the main cause being the urban growth, where these areas were transformed for economic or recreational purposes. Moreover, 8,000 to 10,000 hectares of barren land have been reduced. Table 1 shows the increasing and decreasing trend of various land uses.

In 2019, waterbodies were reduced. Many small waterbodies, which were present in 1992 were missing in the 2019 map. Built-up land covers the areas near the coastal belt, and barren lands have turned into residential areas. Built-up areas cover nearly 55,000 hectares of land. Cochin international airport, which is built in 1994, is located near a tank. Agriculture area has been lessened due to human intrusions, and many farming areas are converted into built-up land. Nearly 125,000 hectares of land was covered by agriculture in 2019. Forest land was reduced from 1992 due to deforestation activity. Barren land has reduced from 1992 to 2019; the main cause being the urban growth, where these areas were transformed for economic or recreational purposes. Moreover, 8,000 to 10,000 hectares of barren land have been reduced. Table 1 shows the increasing and decreasing trend of various land uses.

Comparison of landuse and Land cover (1992-2019) and Accuracy Assessment

For accuracy assessment, a total of 50 random sample points was created for each classified image and estimating kappa statistic using accuracy assessment module available in ERDAS IMAGINE. From the results, the overall classification accuracy as obtained from the classified images was observed to be 96.90% and 92.01% with kappa statistic 0.945 and 0.89 for the years 1992 and 2019 respectively. From the table, it shows that many land use classes have changed. Some of the areas which were earlier under waterbodies have been transformed into settlements. Almost 32,000 hectares of farming land have been converted into settlements. The areas near Aluva and Alappuzha have changed into urban centres. Approximately 450 hectares of forest areas have transformed into settlements. Over 9500 hectares of barren lands have transformed into settlements.

Table 1. Land Use Land Cover (1992 to 2019)

Class Number	Class Name	1992 (Area in Hectare)	2019 (Area in Hectare)
1	Waterbodies	23989	21551.2
2	Settlements	12457.7	54763.7
3	Agriculture	144126	125093
4	Forest	72134.8	59690
5	Barren Land	53162.9	45336.3

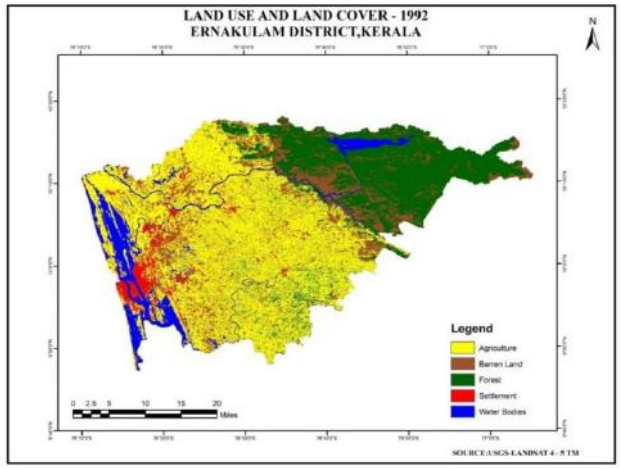

Fig. 3. Landuse Land Cover of Ernakulam District (1992)

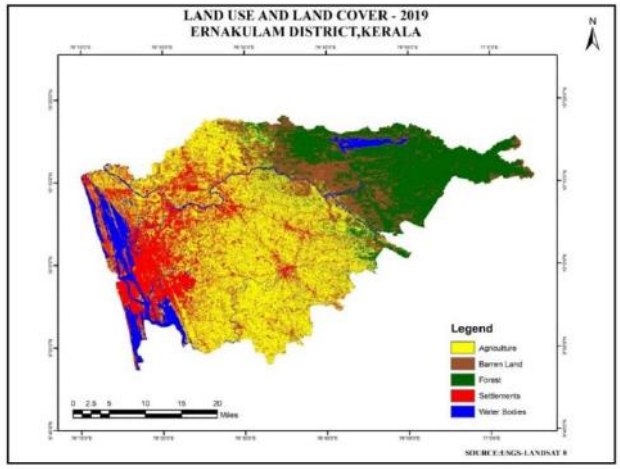

Fig. 4. Landuse Land Cover of Ernakulam District (2019)

Table 2. Error Matrix (1992 and 2019)

Classes Names	1992		2019	
	Producers Accuracy	User Accuracy	Producers Accuracy	User Accuracy
Agriculture	93.33%	94%	75%	98%
Barren Land	95%	95%	88.24%	88.24%
Forest	96.31%	95.31%	88.33%	88.33%
Settlements	85.71%	88.89%	90%	81.12%
Waterbodies	94.29&	82.50%	97.73%	93.48%
Overall Classification Accuracy	96.90%		92.01%	
Kappa Statistics	0.945		0.89	

Table 3. Change Detection (1992 to 2019)

Class Name	Waterbodies	Settlements	Agriculture	Forests	Barren Lands
Waterbodies	0	1603.53	1889.46	19.98	637.74
Agriculture	935.55	32827.5	0	3052.62	12260.1
Forest	119.97	455.76	8508.15	0	13169.7
Barren Lands	535.77	9519.57	177665.5	6684.93	0

Water Indices

The use of remote sensing for water body extraction began many years ago, and then different types of water indices have been developed (Zhang et al. 2018). Some of the important water indices are the normalized difference water index (NDWI) (McFeeters 1996) and the Modified Normalized Difference Water Index (MNDWI) (Xu, 2006). The earlier one takes the green and the N.I.R. band for water body evaluation. Yet, NDWI could not efficiently extract water as it mixed up built-up features with water area to be considered and consequently exaggerated water (Xu 2006). The modified normalized difference water index (MNDWI) was developed to succeed in this problem. It uses the green and the mid-infrared band instead of the near-infrared band and is found to be more accurate. In recent years, new water indices have been developed which use more than two bands to improve spectral differentiation and water feature delineation. Automatic Water Extraction Index (AWEI) developed by (Feyisa et al. 2014). Fisher et al. (2016) developed Water Index2015 (WI2015), which includes five bands.

Although newly formed, AWEI is widely used along with MNDWI for water body extraction and mapping (Guo et al. 2017b). Other purposes are to facilitate the analysis of the change in waterbodies and support research into the long-term trends of water extent (Fisher et al. 2016). In this respect, these three indices are chosen for the present study to verify the correctness of these indices under a specific landscape situation and water surface area changes in Ernakulam District.

Normalized Difference Water Index (NDWI)

(NDWI) was first suggested by (S. K. McFeeters, 1996) to identify surface waters in wetland environments and to allow for the measurement of surface water dimensions. NDWI for T.M. and O.L.I. sensor is defined as the equation (Verpoorter, 2012)

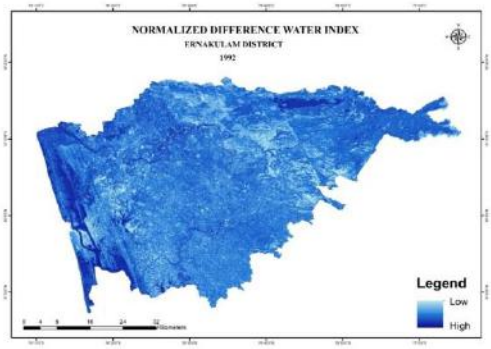

Fig. 5. NDWI 1992

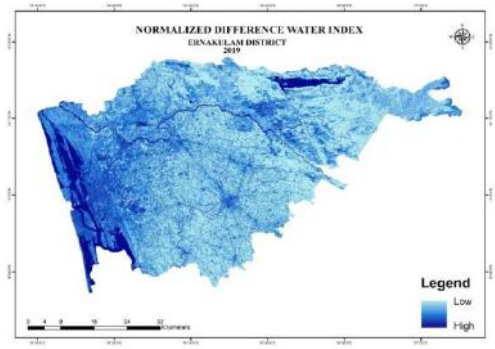

Fig. 6. NDWI 2019

NDWI = (Green – NIR) / (Green + NIR)

Where, Band2=Green, band4=NIR for Landsat 4-5 TM.

Band3=Green, band5=NIR for Landsat 8 OLI/TIRS

Modified Normalized Difference Water Index (MNDWI)

McFeeters (1996) proposed the Normalized Difference Water Index (NDWI). The Normalized Difference Water Index (NDWI) results in water features with positive values. On the other hand, vegetation and soil typically come out at zero or negative values (McFeeters 1996). The modified normalized difference water index (MNDWI) can be expressed as follows:

MNDWI = ($Green$−SWIR)/($Green$+SWIR)

Where, Band2=Green, band5=SWIR for Landsat 4-5 TM

Band3=Green, band6=SWIR for Landsat 8 OLI/TIRS

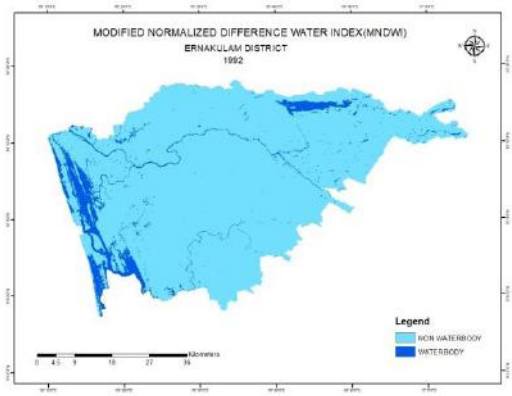

Fig. 7. MNDWI (1992)

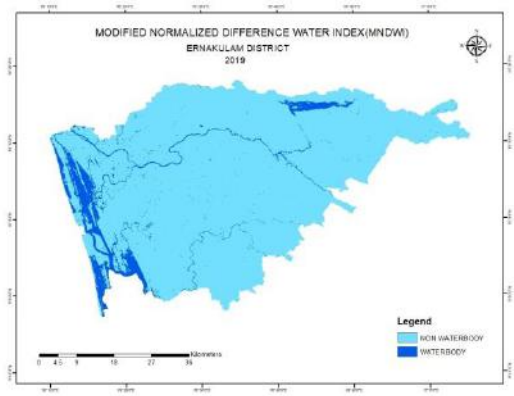

Fig. 8. MNDWI (2019)

Automatic Water Extraction Index (AWEI)

The Automatic Water Extraction Index (AWEI) was developed by Feyisa et al. (2014). The purposes for developing of AWEI were (a) to automatically suppress classification noise from shadows and other non-water dark objects and to improve the precision of surface water mapping, (b) to investigate the robustness of the new method under diverse environmental conditions as well as to evaluate the relative accuracy in comparison with existing classification procedures. The selection of spectral bands, their arithmetic combinations, and the coefficients for the development of AWEI equations was based on the rational inspection of various land features' reflectance characteristics. Based on environmental and landscape conditions, Feyisa et al. (2014) have developed equations.

AWEI = 4 × ($Green$–$SWIR1$) − (0.25 × NIR + 2.75 × $SWIR2$)

These equations were based on the spectral reflectance value form the Landsat 4-5 TM imageries, where band1=Blue, band2=Green, band4=NIR, band5=SWIR1, and band7=SWIR2. And from the Landsat 8 OLI/TIRS imageries, band2=Blue, band3=Green, band5=NIR, band6=SWIR1, band7=SWIR2. These equations aim to put non-water pixels below zero (0) and water pixels above zero (0).

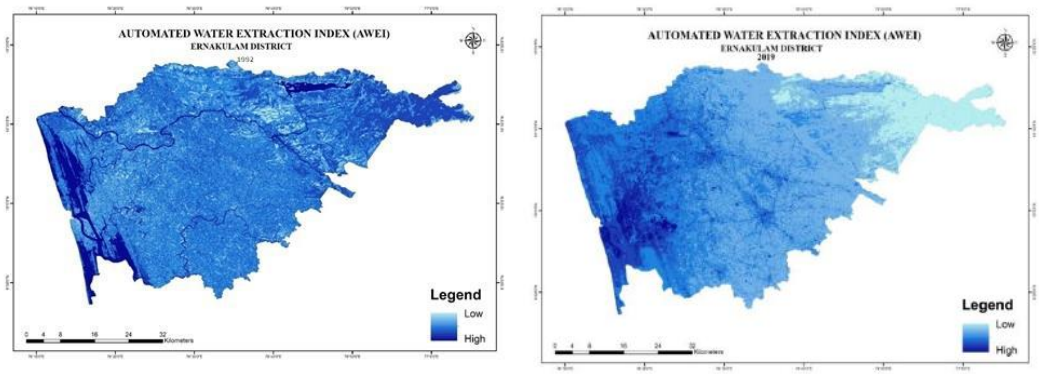

Fig. 9. Automatic Water Extraction Index (a) 1992 (b) 2019

The four spectral water indices (NDWI, MNDWI, AWEI) are applied to the lake water area to highlight the differences between water and non-water areas. NDWI water areas are generally having values greater than zero. So this index is useful to extract the surface water. MNDWI images are classified into water and non-water using a threshold of 0 (S. K. McFeeters, 1996). It separates water and non-water objects well, with water areas generally having values higher than zero and vegetation areas having a substantial negative value. The optimal threshold value for the AWEI is recommended by (G. L. Feyisa, 2014) varies from −0.15 to 0.045. In this study, the threshold value was accepted 0 due to provide consistency between all applied indices. Landsat imagery is the most popular data source for calculating water indices due to its suitable spectral bands and medium spatial resolution. It is clear from maps that water bodies are easily discriminated from all of the three water index images. It is also noted that MNDWI images have higher contrast in this case. All three indices show the extraction and detection of water bodies. This study has discussed the change in the landuse and landcover of Ernakulam District using the geoinformatics techniques. Around 2400 hectares of water bodies have been lost in the last 27 years. Settlement areas have increased 5 times in the study area replacing the water bodies, agricultural land, forest cover and the barren lands. Supervised classification method was used to classify the image and accuracy assessment has shown overall accuracy to be 96.9% and 92.1% for the years 1992 and 2019 respectively. Different indices have been used to understand the most efficient method to extract waterbodies. NDWI and MNDWI show better results than AWEI.

However, NDWI could not achieve likely accuracy in water feature evaluation with built-up surroundings. The estimated water pixels in that area mixed with built-up noise indicated that pixels from built-up features might have a positive value and are classified as

water. Examining the spectral reflectance of water features, vegetation, and built-up areas, authors found that the reflectance pattern of built-up and water features are similar in the green and N.I.R. band in T.M. image. This is why the enhanced water presence in the NDWI-image is often mixed with built-up land noise.in this condition use of MNDWI is used. The MNDWI presented with three results: (a) water obtained more refined positive value than NDWI due to greater consumption of SWIR (b) built-up areas displayed negative values (c) soil and vegetation also produced negative values as reflects more SWIR light than NIR. In AWEI a default threshold zero (0) was used at the first step; however, there were possibilities that due to the variation among scene contrast and brightness, acquisition time and space, the default threshold might not give a proper extraction of water.

Conclusion

This paper is focused on the temporal change of water bodies of Ernakulam District Kerala, using remote sensing techniques and geographic information systems. Five techniques are applied to detect the change of the surface water bodies by using ERDAS Imagine and ArcGIS software. It has been clearly explained in the paper, that the water resources, especially in the urban areas, are 'mismanaged' because of human interference in the name of development. Extend of the city limit, an increase in the population and many anthropogenic activities have been carried out near the water bodies, which has worsened the water bodies condition more. The analysis results reveal that the water bodies have shown very major changes in their surface area coverage over the past decades. If such a decreasing trend in water bodies, especially lake, continues, the lake will likely lose its entire water surface shortly. Further, a new approach was introduced for surface water change detection based on NDWI, MNDWI, and AWEI. The study demonstrated high performance of the proposed approach in simultaneously detecting the surface water changes between two time periods. The result shows better change detection using NDWI, MNDWI, and does not work well with AWEI. For smaller water bodies, mid resolution Landsat image pixels were unable to detect the water, whereas it is vice versa for the larger ones. In conclusion, the water extraction indices like NDWI, MNDWI has been proven to be effective in detecting the water surface changes in Ernakulam. Accordingly, the methods may prove useful in studying other surface waters in the world as well as flood monitoring.

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SHIFTING OF MONSOON ONSET AND UNDERSTANDING ITS EXPECTED IMPACT ON ENVIRONMENT IN INDIA

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Abstract

The shifting of monsoon onset has a lot of consequences for the environment. India is a vast country with mostly hot tropical climate expect the Himalayan region of the country. In the present study, we analysed the shifting of monsoon onset from 1960-2019. The trend of the onset of monsoon was observed by considering the change point existence with the help of Buishand Range Test. The length of the monsoon onset season was also investigated using anomaly of the monsoon onset season and standard deviation. We found the shortening of the monsoon onset season and trend showing delay in monsoon onset.

Keywords: Monsoon Onset, Environment, Impact, Rainfall, Dynamics

Introduction

Indian summer monsoon has a lot of importance for the country due to its direct relation with the Indian economy. The huge size of the world's population lives in this region and depends on monsoon seasonal rainfall. Along with the large contribution of monsoon rainfall to the total annual. Timing of monsoon onset plays a very important role. The early or late onset of monsoon has a lot of repercussions for human society and the biodiversity in the region. India Meteorological Department (hereafter IMD) has maintained a large network of stations across India to obtain the amount of rainfall received. In addition to this, IMD is the government agency in India to define, identify and announce the onset of monsoon. Monsoon is known as the seasonal reversal of winds causing rainfall in the region. In the recent past, changes in the monsoon rainfall are noted across different monsoon region. Changes in the monsoon rainfall over the Asian monsoon region (especially China) is notable (Zhao et al. 2010; Ding et al. 2008). There can be many reasons behind the changing rainfall but an increase in carbon and aerosol is found the primary among all (Ramanathan et al. 2001). Among other factors responsible for the amount of rainfall received, the onset of monsoon is very important. Late-onset of monsoon is found the major cause of loss in agricultural produce (Krishna et al. 2004; Prasanna 2014), the occurrence of drought and heatwaves. Therefore, in the present study by following the set objective, we attempted to analyse the trend of monsoon onset and monsoon onset season in India (Figure 1). In addition to this, the study also attempts to

understand the impacts on the environment with general monsoon dynamics and changing monsoon onset.

Study Area

The whole study is based on India with a hot tropical climate. It covers 5 homogenous monsoon regions delineated by the IMD and discussed by (Parthasarathy et al. 1993). These homogenous monsoon regions as discussed by Parthasarathy et al. (1997) are delineated based on four criteria – (a) Areal contiguity, (b) Monsoon season's rainfall to the total annual rainfall, (c) Correlation between sub-divisional rainfall and all Indian monsoon rainfall amount, (d) Interrelation between monsoon rainfall of sub-divisions and regional/global circulation parameters. Five homogenous monsoon regions covering the present study are– (a) Northwest (b) Central Northwest (c) Northeast (d) West Central and (e) Peninsular. In this study, we did not consider the Hill Region due to the unavailability of monsoon onset data for the region and no available objective methodology to calculate the monsoon onset for the Hill region. Northwest region of the study area has arid and semi-arid climate region and therefore the region does not have a high density of population. Though, the population of Rajasthan and Gujarat has a large surface area. Central Northwest region has Uttar Pradesh, Bihar, Jharkhand and Odisha states. Central Northwest region has a very large size of the population and it makes a huge part of the total population of India. The Gangetic plain feature of the region makes highly suitable conditions for agriculture on the fertile land. Northeast region of the study area is made with West Bengal, Sikkim and all the seven sister states i.e. Assam, Meghalaya, Arunachal Pradesh, Manipur, Mizoram, Nagaland, Tripura. This part of the study area has the highest density of forest with the most part covered with it. West Bengal in this region has a very high density of population.

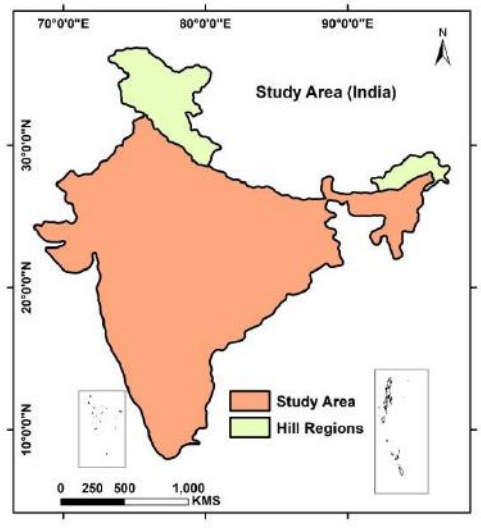

Fig. 1. India

Source: *Drawn by the author based on boundaries of homogenous monsoon region delineated by India Meteorological Department and mentioned in Kothawale and Rajeevan (2017).*

All the seven sister states of the Northeast region have very high biodiversity and its biodiversity is acknowledged by IUCN as the hot spot at the global level. West Central region consists of Maharashtra, Madhya Pradesh and Chhattisgarh. West Central Region is the plateau region and makes the central part of the Indian mainland. Previous studies showed a high impact on the region's monsoon rainfall amount due to the warming trend of the western Indian Ocean (Koll et al. 2015). In this region economy of Maharashtra make more than 30% of India's gross domestic product. The Vidharbha and adjacent area of this region is highly vulnerable to drought. The peninsular region has Kerala, Karnataka, Goa, Telangana, Andhra Pradesh, and Tamil Nadu. The peninsular region has the Western Ghat region, which is the eight hottest biodiversity hotspot of the world. In addition to this, the region is the hub of tea, coffee and species production. The peninsular region also has major cities like Bengaluru, Hyderabad, Chennai, Cochin etc.

Database and Methodology

Monsoon onset data from 1960 to 2019 was calculated using the objective criteria provided in the technical report of the Indian Institute of Tropical Meteorology (Singh and Ranade 2010a). Monsoon onset data obtained from objective criteria provided by the Indian Institute of Tropical Meteorology is to identify the onset and withdrawal of monsoon for different sub-regions. Sub-regions in the present study are identified on the basis of the identified sub-regions in the technical report RR-124 of Indian Institute of Tropical Meteorology (Singh and Ranade 2010a). Many sub-regional classifications for a different purpose, for example hydrological, agricultural, ecological etc. classification has been done for India. Which was not suitable for the study of the onset of monsoon in India at sub-regional scale, therefore six physical-climatological factors were considered for the delineation of sub-regions in India (Singh and Ranade 2010b). Six factors considered by Singh and Ranade (2010b) are– (a) Topographic features, (b) Spatial pattern of monsoon and annual rainfall, (c) Physiographic characters, (d) Drainage pattern, (e) Normal onset and withdrawal of monsoon, and (f) Daily rainfall data. The calculated mean date for each year (for period 1960-2019) from all the sub-regions (sub-regions as mentioned in Singh and Ranade 2010a) is considered as the date representing the study area in the present study (Figure 1).

Monsoon onset for different sub-regions was calculated using the objective method but it was not available for the 'Hill Region' covering the Himalayas with highly representative manner. Therefore, Hill region (Figure 1) is not part of the present study. Reanalyzed data was used for understanding the general dynamics of monsoon onset season at different levels of the atmosphere concerning the onset of monsoon. Data of 1°x1° spatial resolution for zonal wind, meridional wind, specific humidity and omega were obtained from NOAA/CIRES/DOE 20th century reanalysed version (Compo et al. 2011). Using the monsoon onset data, we identified the trend of monsoon onset for India. The anomaly of the monsoon onset was calculated for each year by considering the mean value for the period 1960 to 2019 as the base period. For the convenience of explanation and easy understanding, we converted the date of monsoon onset into the Nth day of the year starting from 1st January as 1 and 31st December as 365.

Trend analysis of the monsoon onset in India was done using linear regression model (equation 1) and the existence of change point was identified using Buishand range test (Buishand 1982) for the period 1960-2019. Here in equation (1) Yi is the dependent variable, β_0 is Y-intercept of population, β_1 is the slope coefficient of the population, X_i is the independent variable and ε_i is the random error term.

$$\mathrm{Y_i} = \beta_0 + \beta_1 X_i + \varepsilon_i \quad \textbf{(1)}$$

Changepoint detection using the Buishand rage test was completed using the equation (2) and equation (3). Existence of change point in the trend shows the sudden change in the trend and therefore it brings the ambiguity in the long term trend. Therefore, Buishand range test was adopted to identify the significant change point to overcome such restriction in genuine trend identification. The adjusted partial sum for the Buishand range test is expressed as given in equation (2). In case of existence of homogeneity in the data series, the rise in the value of S_y^* occurs and settles near zero. The year is denoted by *y* in the equation and observes the changepoint when the value of S_y^* reaches the maximum (negative shift) or minimum (positive shift). *R* in the equation (3) represents the rescaled adjusted range and is calculated using the formula in equation (3)

$$S_0^* = 0 \; and \; S_y^* = \sum_{i=1}^{y} (Y_i - \bar{Y}), \; y = 1,2 \ldots\ldots, n \quad \textbf{(2)}$$

$$R = \frac{\max\limits_{0 \le y \le n} S_y^* - \min\limits_{0 \le y \le n} S_y^*}{S} \quad \textbf{(3)}$$

Having calculated the value of $R/\sqrt{n}$ is compared with the given critical values by Buishand (1982). In addition to it, the length of the monsoon onset season was calculated by the existing difference between monsoon onset in Peninsular region and the Northwestern region. monsoon onset season in the present study is simply the period between the onset in Peninsular region and onset in the Northwest region of India. Both of these regions were selected for calculation of the seasonal length due to their characteristics of first onset (Peninsular region) and last onset (Northwestern region). Moreover, the deviation from the calculated normal of the anomaly of the monsoon onset season is calculated using the ±1 standard deviation. We considered ±1 standard deviation criterion for detection of the years with a large scale of deviation. ±1 standard deviation covers 68% area on the normal curve and therefore it explained the events which are not part of the 68% cases of the anomalous length of monsoon onset season's length. The standard deviation was calculated using the below-given formula in equation (4) (Lee et al. 2015; Wan Nor 2014). In equation (4), σ represent the calculate standard deviation, N is the size of the population, μ means the mean of population and x_i represents the value of each point of the population.

$$\sigma = \sqrt{\frac{\sum (x_i - \mu)^2}{N}} \quad \textbf{(4)}$$

Impact on the environment in India due to the shifting of monsoon onset was analyzed in general. The analysis is based on the general characters of India based on the physiography, population size and type of activities for livelihood security of the majority of the population and biodiversity in a different region.

Results and Discussion

Long term trend (1960-2019) of monsoon onset shows an increasing trend in the monsoon onset day in India. We observed a large fluctuation at places in the trend line of monsoon onset (Figure 2a). Therefore, a better trend was obtained by identifying the changepoint. We found the reversal in trend after the first changepoint and it signalled the early onset. Besides the reversal of the trend from a positive to negative, it is found that onset tendency after the second changepoint remained in agreement with the long-term positive trend for the period 1960-2019. The first changepoint existed in the year 1972 and the detection of changepoint was not highly significant as per the p-value obtained through the Bushland range test. For the period 1973-2019, the trend was negative but with very low significance (Figure 2b). Therefore, we further identified the significant changepoint and changepoint significant at 95% level was obtained in the year 1988.

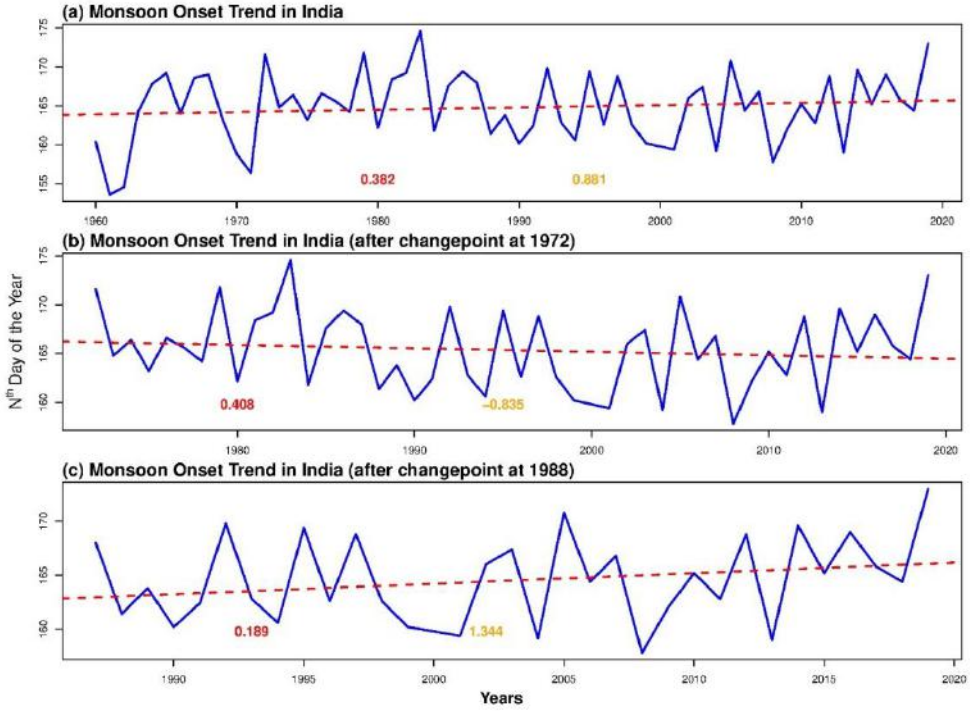

Fig. 2. The trend of monsoon onset in different periods. (a) monsoon onset trend for 1960-1972 (b) monsoon onset trend for 1973-1988 and (c) monsoon onset trend for 1989-2019. Blue solid line is for the linear trend of monsoon onset and ted dotted line represents the regression line. Number in red represents the p-value and yellow represents the magnitude of the trend.

For the period 1989-2019, linear trend results also improved in comparison to long term trend (1960-2019) and the period after the first changepoint (1973-2019) and it became significance at 80% level of significance with high magnitude of 1.34 days increases per year (Figure 2c). Considering changepoint existence, it is interesting to note that the day of mean onset for all the three periods i.e. 1960-2019, 1973-2019 and 1989-2019 remained 165th day (14th June).

Length of Monsoon Onset Season

The length of the monsoon onset season determines the survival of a lot of livelihood activities and provides great strength for the survival of the ecosystem on the earth's surface. The longevity of the monsoon onset season is one very important catalyst for the Indian economy and therefore we analyzed the changing length of the monsoon onset season in India. Analyzing the yearly anomalous monsoon onset season length in India, we found three different phases of monsoon onset season length (a) 1960 to 1980, (b) 1981 to 1995 and (c) 1996 to 2019 (Figure 3). Here, three different phases as shown in figure 3 were identified based on the change-point detection (significant at 95% level) using the Buishand range test as discussed in sub-section 'Trend of Monsoon Onset' and section 'Data and Methodology' (Buishand 1982). The average length of the monsoon onset season in the first delineated phase was 24 days, 26 days in the second phase and less than 23 days in the third phase representing the most recent period. In addition to the mean length of monsoon onset season in different phases, events with +1 (-1) standard deviation in the first phase were 3 (2), 4 (1) in the second phase and 3(6) in the third phase respectively. It becomes evident from figure 3 that the length of the season has decreased a lot in the recent phase and it might be the cause of increasing extreme events leading to flooding. In the recent phase (1996 to 2019) the maximum number of negative anomalous years occurred.

During the monsoon onset season, stimulus and moisture content remains the same but the swift progression of it in short span leads to extreme events especially the flood. Reason for the swift progression of monsoon needs further in-depth research study. Urban areas of the country have faced some huge flood events in the past one decade and therefore dynamics behind the decrease in monsoon onset seasonal length must be investigated as the cause behind increasing extreme events causing floods and other climatic events.

Decadal analysis in Table 1 shows that the number of events with +1 standard deviation was 2 in the first decade and it kept on fluctuation before reaching its lowest in the recent decade. It means that the years having large monsoon onset season have touched its lowest. Whereas, years with -1 standard deviation representing the short monsoon onset season have increased in number along with the total number of negative anomalous years showing short season. It simply indicates the shortening of monsoon onset season as clearly represented by the trend line in Figure 3. The recent decade has also observed the shorted monsoon onset season in comparison with the other decades (Table 1).

Table 1. Decadal length of the monsoon onset season, seasons with large and short length than the calculated mean for the period 1960-2019. The value for the large (short) monsoon onset season shows the number of years with ±1 standard deviation for their respective categories.

Decade →	1960-1969	1970-1979	1980-1989	1990-1999	2000-2009	2010-2019
Length of Monsoon Onset Season (in days)	26	23	27	24	25	22
Large Season (in numbers)	6 (2)	4 (1)	4 (3)	4 (1)	4 (3)	4 (0)
Short Season (in numbers)	4 (1)	6 (1)	6 (1)	6 (2)	6 (2)	6 (2)

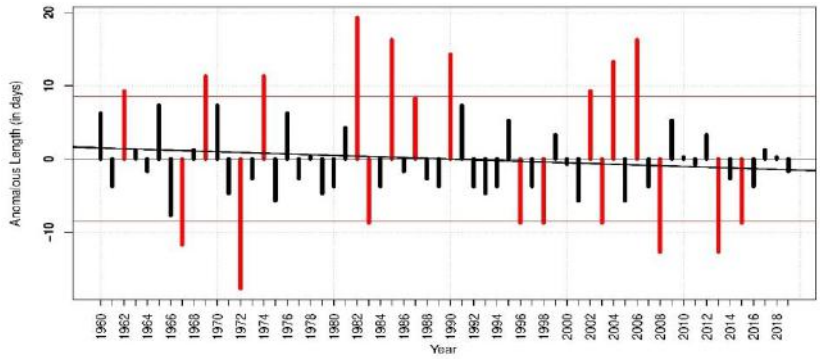

Fig. 3. The anomaly of the monsoon onset season in India for the period 1960 to 2019. The length of the season is calculated based on the onset in Peninsular region (first onset) and Norwest region (last onset). The calculation of anomaly is based on the climatology calculated for the length of season for the period 1960 to 2019. The horizontal red colour solid line shows the mark of ±1 standard deviation and the bars surpassing ±1 standard deviation are marked with a red colour.

Dynamics of Monsoon Onset and Impact of Shifting Monsoon Onset

A very important study (Koll et al. 2015) found the impact of West Indian ocean warming on the South Western monsoon rainfall over the Indian region. In this study, while investigating the dynamics of monsoon onset season, we calculated the mean prevailing conditions of wind, omega (vertical velocity) and specific humidity for the period 1960-2019. We found that the wind vectors at the level 1000-950 mb strongly support the directional movement of monsoon (Figure 4). The intensity of wind dissipates in the interior of the Indian mainland (especially in Central Northeast and Northwest). Figure 5 shows that the specific humidity at almost all the pressure levels remains comparatively less in the Northwest and Peninsular region. A combination of wind and specific humidity is one very necessary condition for rainfall occurrence. In addition to both of them, vertical velocity provides a platform for carrying the available moisture transported through the wind to a higher level. It ultimately transforms into a condensation process leading to precipitation. Hence, here through Figure 6 showing vertical velocity with higher intensity at 850 mb (Figure 6f) level supports the conditions for heavy rainfall. Though a lot of regional climatic complexities bring adverse conditions for monsoon onset and rainfall.

Based on obtained results and combined climatic conditions of wind, omega (vertical velocity) and specific humidity, it can be asserted that shortening of the monsoon onset season will highly impact the Peninsular, West Central and parts of Northwest region with flood-like extreme events. This cases of increase in the flood like extreme events are due to the short span of the monsoon onset season, high specific humidity, high wind and high omega in these regions. The occurrence of these conditions with the movement of monsoon in these regions will lead to heavy rain and a deficit of moisture for rain in other regions.

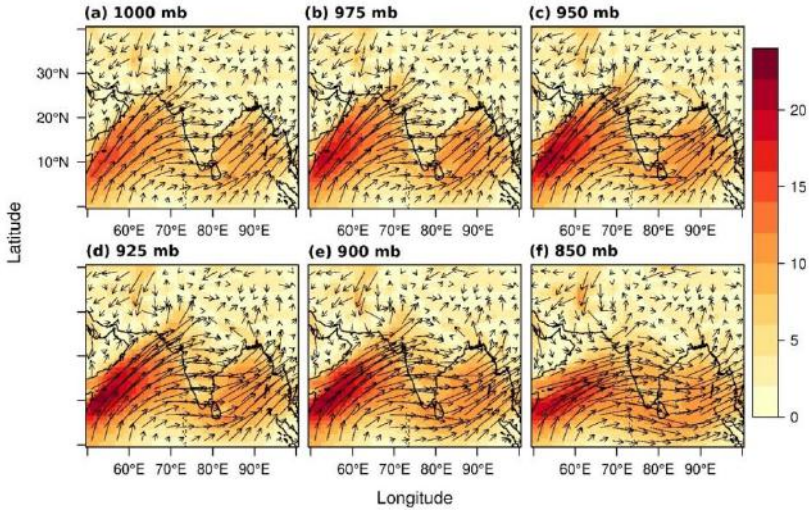

Fig. 4. Wind vectors showing the movement at all the pressure levels (1000 to 850 mb) near the surface during the mean monsoon onset season for the period 1960-2019. The unit of the wind is meter/sec.

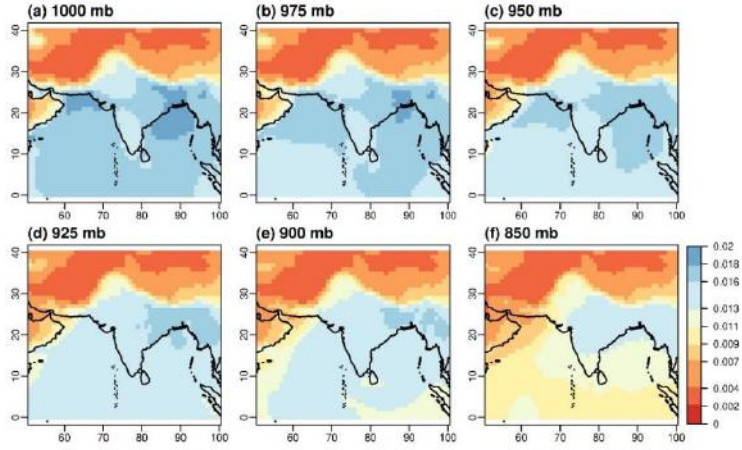

Fig. 5. Specific humidity at all the pressure levels (1000 to 850 mb) near the surface during the mean monsoon onset season for the period 1960-2019. Unit of the Specific humidity is kg/kg.

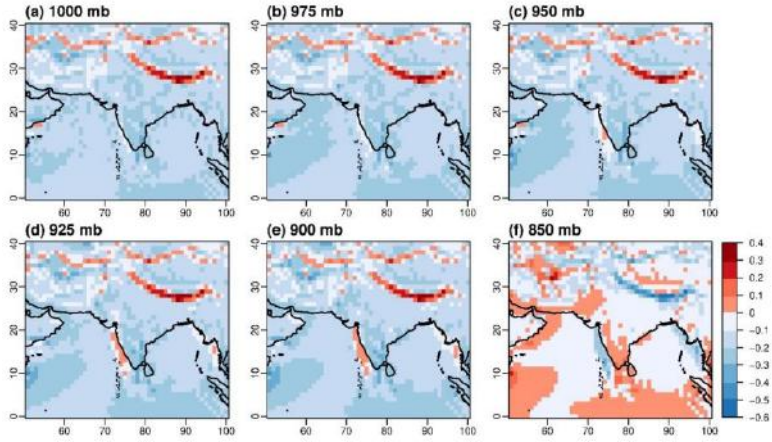

Fig. 6. Omega at all the pressure levels (1000 to 850 mb) near the surface during the mean monsoon onset season for the period 1960-2019. Unit of the Omega is pascal/sec.

Heavy rainfall events in the arid and semi-arid region will lead to mudflow in the region and it will impact the environment in all its dimensions. Whereas, heavy rainfall in West Central and Peninsular region has already started showing its huge impact in the coastal regions of Kerala, Goa and Maharashtra. Frequent flood in Mumbai, frequent landslide and heavy rainfall events in Kerala are some emerging examples. Here it should be noted that the Central Northeast region is known for its huge agriculture production and heavy rainfall in Southern India will cause the absence of required moisture and break of monsoon rainfall for Central Northeast. The continuity in the prevalence of such conditions will lead to drought-like conditions in the Central Northeast region of India. It will be harmful to Indian food security and self-reliance on the availability of the food grains for the second largest population of the world. In the Northeast region, the early onset of monsoon will lead to disturbance in the occurrence of a lot of local festivals and cultural practices along with monsoon onset. Early-onset does not mean enlargement of the monsoon season. It means that the changing of general practice for the livelihood security by the majority of the tribal population.

Conclusion

Shifting of monsoon onset was assumed to be a reality but no scientific evidence was available in plenty to support the narrative. The present study is an attempt to fill that gap. Using the linear regression model, the general trend of the Indian monsoon Onset was deciphered. The trend for the monsoon onset shows the late onset of the monsoon for India and the magnitude of the trend is also very high with 1.344 days per year. Continuity in such trend will bring a lot of harsh impact on the environment in India. The magnitude of the trend of monsoon onset after two different detected changepoints i.e. in the year 1972 (insignificant) and 1988 (significant at 95% level) shows a reversal of the trend. Whereas the significant trend at the 80% level for the period 1989-2019 is in line with the long-term trend of the monsoon onset.

The length of the monsoon onset season was also analyzed using the calculation of anomaly and the years with ±1 standard deviation also helped to estimate the years with large scale variation in different phases of the whole period (1960-2019). We found shortening of monsoon onset season and adverse probable impacts of its shortening on the environment. The impact of the shifting of monsoon onset will be very high on the coastal part of Kerala, Goa, Maharastra, Gujarat and Coastal Andhra Pradesh. West Central region is found to be on the verge of facing frequent drought events in the long term and its occurrence is a huge danger for the agricultural production in the Indo-Gangetic plain. An in-depth study to understand the dynamics behind the shortening of monsoon onset season and delaying of monsoon onset will be very important to understand the real mechanism operating for the occurrence of such conditions.

Acknowledgement

We are highly thankful to the University Grants Commission for continuous financial support as a UGC-Senior Research Fellow to Atul Saini. The 20th century reanalyzed data was obtained from the online platform provided by NOAA Physical Sciences Laboratory. Ratan Tata Library provided access to digital platforms for the completion of the present study.

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IMPACT ON CHANNEL PLANFORM CHANGE OF DIKRONG RIVER ON LANDUSE/LAND COVER USING REMOTE SENSING AND GIS

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Abstract

Channel planform of the alluvial river is frequent changes which cause many of the geomorphic hazards due to bank erosion which causes lateral migration of river. The channel planform change and its impact on landuse/ landcover were investigated along a 30.55 Km section of the Dikrong River in Assam for a period of 46 years (1973 to 2019). To determine the channel dynamics, the morphometric characteristics were measured and analyzed by using the Landsat and Sentinel imageries in GIS. The results revealed that the river has gone through a phase of channel straightness (1999-2009) through lateral bank erosion, channel migration and meander cut-off during 1989-1999. As a result, around 24.45 km2 of agricultural and forest area got eroded.

Keywords: *Channel dynamics, Morphometric, Bank erosion, Channel straightness*

Introduction

The implication of rivers in the development of landscapes has always mesmerized geomorphologists, hydrologists, and geologists from a long period of time (Mueller, 1968). The lateral channel shifting, which is adequately rapid on many large rivers, is a geomorphic action, which has the potentiality to generate catastrophic changes in the local and regional level (Hickin, 1983). The people living near the riverbank area always remain vulnerable due to such river actions like changes in the river course and channel morphology (Das et al., 2012)and with the passing of time, some possible human adjustment has been developed to cope up with this nature especially during the flood and bank erosion (Haque, 1988). As the geomorphic phenomena are dynamic in nature, Remote Sensing and Geographical Information System (GIS) has become a standard tool for geo-morphological research (Vitek et al., 1996) because monitoring and observing lateral bank erosion and channel migration through traditional methods and techniques are more time and resource consuming (Bordoloi et al., 2020). In Assam, interest in this field has grown proportionally amongst the researcher of geomorphology, hydrology and earth sciences (Das et al., 2007; Sarkar et al., 2012; Barman and Goswami, 2015; Bordoloi et al., 2020). Though the emergence of geospatial technology has reduced the workload as well

as enhanced the findings of the research, the fieldwork remains a recognized part of doing the geomorphological study.

Though the geomorphic activities like the formation of distributaries, meandering channel, avulsions and confluence migration are common in the rivers of Brahmaputra, the formation, growth, abandonment and reactivation associated with distributaries are dominantly noticeable over the northern tributaries as well as meander dynamics is also frequently visible over the small north bank tributaries (Sah and Das, 2018). Some studies have been done on flood hazard mapping, landslide hazard zonation, morphotectonic evolution, channel changes, soil loss estimation of Dikrong River (Dabral et al., 2007; Pandey et al., 2008; Bhadra et al., 2011; Bezbaruah and Sarma, 2013; Borgohain et al., 2018). The massive erosion along with flash flood during every monsoon season by the Dikrong River has caused great destruction in many parts of its course. Due to which the river has shifted from its usual course and has engulfed most of the agricultural cropland and settlement areas, which has led to the abandonment of villages. The section of 30.55 Km of the river reflects very dynamically related to the channel shifting. The proper study on the nature of bank erosion and its effect has not been carried out properly. Therefore, this kind of study is important to understand the riverine impact on human being and also will help the policymakers to come up with proper planning.

Study Area

The river Dikrong is one of the major tributaries of Subansiri River. The whole catchment area is located between 27°00' N and 27°25' N latitude, and 93°00' E and 94°15' E longitude having an area of 1,556 km^2 where 1,278 km^2 area is situated in Arunachal Pradesh and rest of 278 km^2 situated in Assam (Pandey et al., 2008). After flowing 113 km in Arunachal Pradesh, the Dikrong River entered in Assam plains and flows 32 km long to meet Subansiri River (Bhadra et al., 2011; SJVN Ltd. 2012). Like other north bank tributaries of Brahmaputra, the river Dikrong also facing a steep gradient especially in Arunachal Pradesh with huge sediment load (Borgohain et al., 2018) and receives heavy precipitation during the monsoon period.

Database and Methodology

Data and its Sources

The satellite image of six different years i.e 1973, 1989, 1989, 1999, 2009 and 2019 obtained from United States Geological Survey (USGS). Table 1 presents detail information regarding the applied satellite images.

Data Processing and Analysis

The geo-referenced images are manually digitized to extract the Area of Interest (AOI) and further analysis has been done using the ArcGIS software (version 10.3). The geomorphic correction of Landsat 7 (ETM+) images of 2009 has been performed using the Landsat toolbox. The riverbank erosion and accretion for each side of the banks and shifting of midline channels were measured following the methods of existing literature of Lovric and Tosic (2016) and Deb and Ferreira (2015).

Table 1. Information Regarding Satellite Imageries

Year	Satellite	Sensor	Band Use	Spatial Resolution	Path/Row	Acquisition Date
1973	Lansat 1	MSS	4,5,6,7	60 m	145/41	15-Nov-1973
1978	Lansat 2	MSS	4,5,6,7	60 m	146/41	5-Dec-1978
1989	Lansat 5	TM	1,2,3,4,5,6,7	30 m	135/41	22-Nov-1989
1999	Lansat 7	ETM+	1,2,3,4,5,7	30 m	135/41	25-Oct-1999
2009	Lansat 7	ETM+	1,2,3,4,5,7	30 m	135/41	21-Nov-2009
2019	Sentinel-2A	MSI	2,3,4,8	10 m	-	5-Nov-2019
						15-Nov-2019

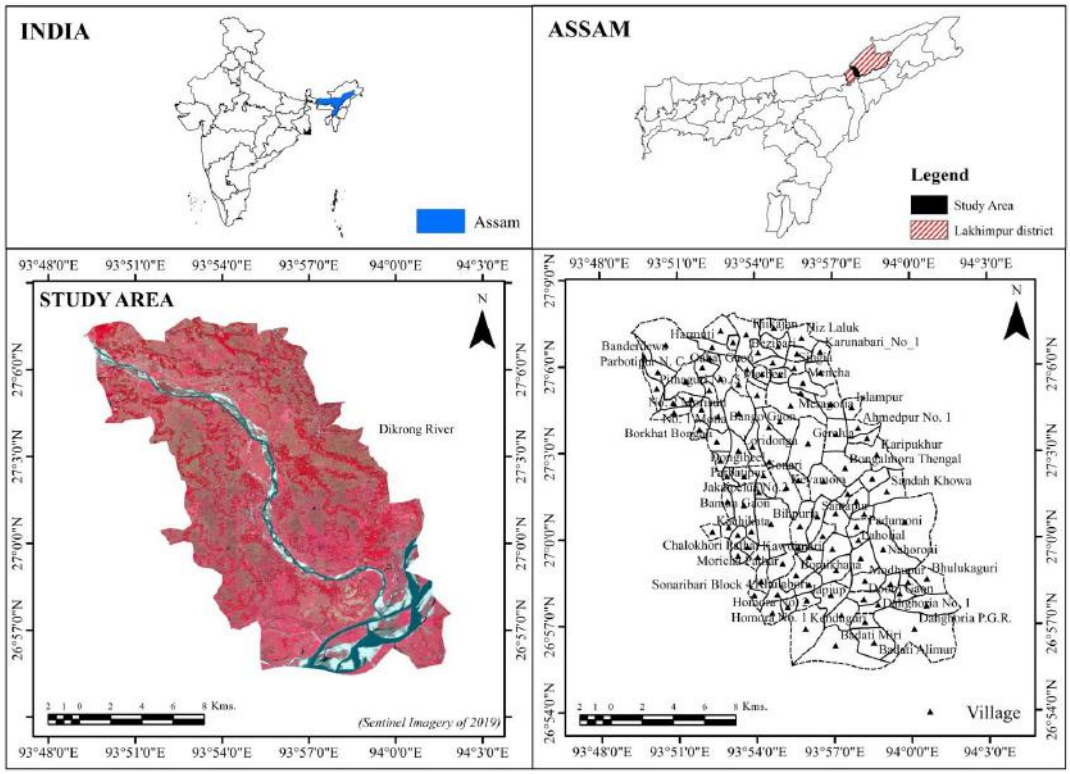

Fig. 1. Location of Study Area

About 38 cross-section lines were considered on the basis of field and visual observation to measure the shifting trend and changing width of the river (Figure 2). The width of the river was measured over every intersection of respective mid-line channel and the cross-section line.

The shifting rates of the channel along the respective cross-sections of a specific time period are measured using the following equation (1)

$$r = \frac{distance\ of mid-line\ channel of\ two\ respective\ time}{No.\ of years\ in\ a\ time\ interval} \quad (1)$$

The mean channel shifting rate during a time interval was measured as per the following equation (2) of Wang et al., (2016) with the alteration of the right bank and left bank:

$$R = \sum_{1}^{n}(a_1 + a_2 + \ldots + a_n)\Big/(n+m) - \sum_{1}^{m}(|b_1| + |b_2| + \cdots + |b_m|)\Big/(n+m) \quad (2)$$

where, '*R*' represents the mean channel shifting rate (metre/year); '*a*' (metre/year, positive) denotes the leftward shifting rate for an intersection point between the mid-channel line and a cross-section; *b* (metre/year, negative) represents the rightward shifting rate for an intersection point between the mid-channel line and a cross-section; '*n*' is the number of the leftward shifted intersection points and '*m*' represents the number of the rightward shifted intersection points; (*n* + *m*) is the total number of the considered cross-sections in a channel. It represents the channel shifted towards left if R is positive, while towards the right when R comes negative. The thalweg length has been measured through the digitizing the centerline of the channel.

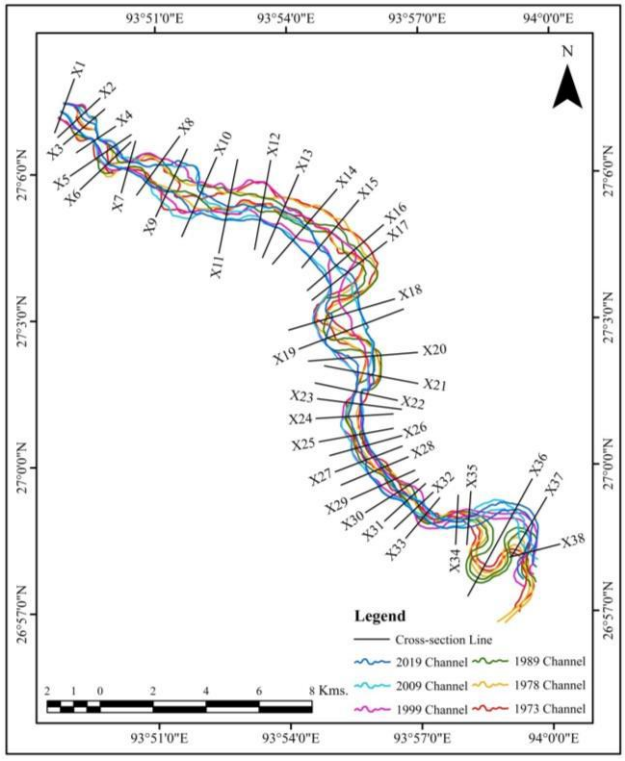

Fig. 2. Cross-Section Line and River Channel of Selected Years

The following equation (3) of sinuosity index (SI), given by Schumm (1963; 1973), has been applied to measure the sinuosity ratio:

SI=(Channel Length)/(Length of the valley) (3)

Results and Discussions

Channel Characteristics

Table (2) reveals an increasing trend of channel length from 1973 to 1989 and a decreasing trend from 1989 to 2019. Accordingly, the thalweg length (line of fastest flow) was increased from 38.37 km. in the year 1973 to 41.78 km. in the year 1989 and thereafter decreased from the year 1989 to 2019 (33.18km.). Similarly, the sinuosity index of the channel increased from 1.43 in the year 1973 to 1.54 in the year 1989 and thereafter decreased to 1.23 in the year 2019.

Table 2. Linear Morphological Characteristics of the Channel

Channel Characteristics	1973	1978	1989	1999	2009	2019
Channel Length (km)	36.00	37.62	38.92	31.54	29.48	30.55
Thalweg Length (km)	38.37	38.84	41.78	32.14	32.89	33.18
Sinuosity Index	1.43	1.47	1.54	1.26	1.19	1.23

Though the sinuosity index (SI) of channels was decreased from 1973 to 2019, an increasing trend of SI was recorded from 1973 to 1989 and a declining trend was recorded from 1989 to 2019 (Table 2). Generally, the declining trend line of SI (R^2=0.645) also represents that the river will become straight in near future (Figure 3).

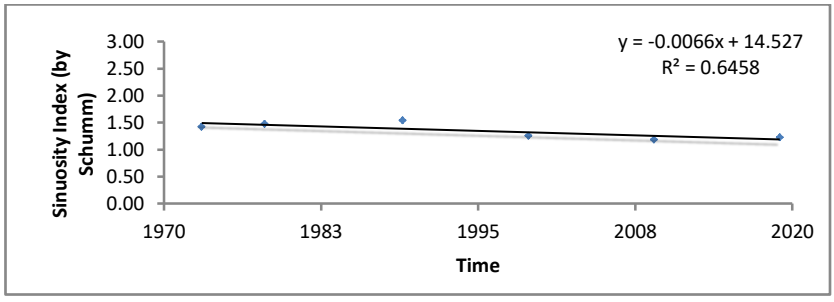

Fig. 3. Variation of sinuosity index with time

Width of the Channel

The channel width reasonably changes within the time period 1973 to 2019 as well as along the channel course (Figure 4). A gigantic change of channel width was recorded over the cross-section X18, X19 and X20, where, the width of the river was increased to 1766.90, 1675.98 and 1124.75 metres respectively in the year 2009 from 374.84, 463.47 and 439.60 metre respectively in the year 1973 with forming an island (0.75 km^2) over the Parbatipur, Gerelua, Keymora and MornoiGaon (Figure 4). Accordingly, in the year 2019, the size of the island increased to 2.30 km^2 but the width was declined to 1083.79, 1553.06

and 820.82 metres respectively. A similar type of changes was also recorded at the cross-section X8, X9 and X10 over the area of Parbatipur No.1 and Pithaguri No.1, where, channel width increased to 1010.18, 1278.02 and 1108.40 metre respectively in the year 1999 from 658.97, 738.28 and 566.70 metres in the year 1973 and further decreased to 759.23, 1220.02 and 802.55 metres respectively in the year 2019 (Figure 4).

Erosion and Accretion along the Riverbank

An area of about 30.506 km^2 suffered bank erosion during 1973 to 2019, where 15.393 km^2 area were eroded from the left bank and 15.112 km^2 area from its right bank (Table 3). Contrary, a total of 27.588 km^2 area accreted during the same time interval where 14.610 km^2 over the left bank and 12.978 km^2 over its right bank (Table 3). The annual yearly rates of erosion were 0.663 km^2 during 1973 to 2019, where, 0.6684, 0.4918, 1.2886, 0.5477 and 0.3391 during the time interval of 1973-1978, 1978-1989, 1989-1999, 1999 to 2009 and 2009-2019 respectively. Accordingly, accretion rate was 0.5997 per year during 1973 to 2019, where, 0.8466, 0.4390, 0.6619, 0.7598 and 0.4309 accreted during the time interval of 1973-1978, 1978-1989, 1989-1999, 1999-2009 and 2009-2019 respectively (Table 4). Generally, the massive erosion and accretion activity was recorded during 1989-1999 and 1999-2009 (Figure 5) where the activity was more prone over the right bank during 1989-1999 and over the left bank during 1999-2009 (Figure 5).

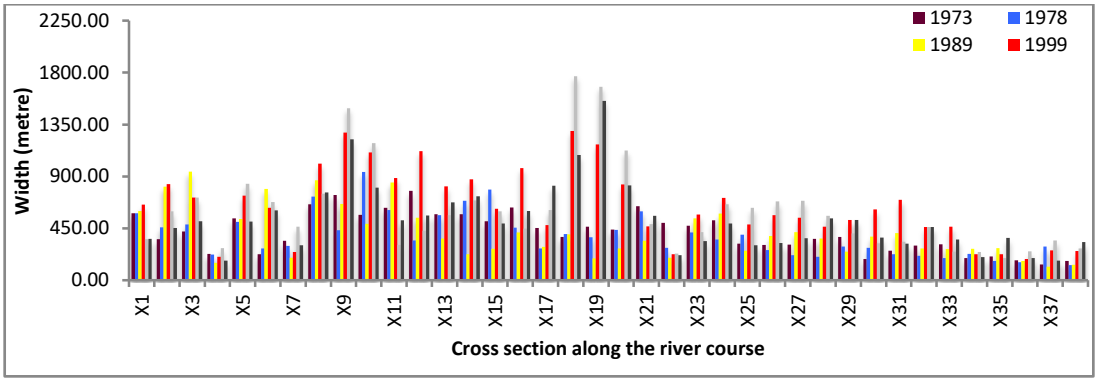

Fig.4. Width of the River Along the Course Section from North to South

Table 3. Area of Riverbank Erosion and Accretion Over the Downstream Dikrong River

Time	Area Where Erosion Occur (km^2)			Area Where Accretion Occur (km^2)		
	Right Bank	Left Bank	Total	Right Bank	Left Bank	Total
1973-1978	1.1487	2.1933	3.3420	2.3580	1.8751	4.2331
1978-1989	2.7079	2.7018	5.4097	2.0688	2.7600	4.8288
1989-1999	6.9502	5.9354	12.8856	3.6336	2.9851	6.6187
1999-2009	2.9000	2.5774	5.4774	1.5157	6.0826	7.5983
2009-2019	1.4057	1.9856	3.3913	3.4018	0.9075	4.3093

Table 4. Rate of Erosion and Deposition

Time	Area Where Erosion Occur (km^2)			Area Where Accretion Occur (km^2)		
	Right Bank	Left Bank	Total	Right Bank	Left Bank	Total
1973-1978	0.0297	0.4387	0.6684	0.4716	0.3750	0.8466
1978-1989	0.2462	0.2456	0.4918	0.1881	0.2509	0.4390
1989-1999	0.6950	0.5935	1.2886	0.3634	0.2985	0.6619
1999-2009	0.2900	0.2577	0.5477	0.1516	0.6083	0.7598
2009-2019	0.1406	0.1986	0.3391	0.3402	0.0908	0.4309
Total	0.3406	0.3220	0.6625	0.2590	0.3106	0.5696

Lateral Channel Shifting

Among the selected 38 cross-sections, 19 cross-sections reflect the leftward shifting of the channel from 1973 to 2019 and the rest of rightward shifting (Figure 6). Although, based on 1973, the river channel of 2019 shifts towards the right due to the higher rate of erosion over the right bank than the left bank (Table 6). During 1973-2019, the highest rightward channel shifts (1350.60 metres with 29.36 $metre^{-1}$) was observed at the cross-section X16, under the area of Bango Gaon and Hoimari No. 79/87 Nlr, where the highest leftward shifting (2600.78 metres with 56.54 $metre^{-1}$) was observed at cross-section X36 of Nahorani village. Similarly, the lowest rightward channel shifting (11.58 metre with 0.25 $metre^{-1}$) and the leftward shifting (41.74 metres with 0.91 $metre^{-1}$) was observed at the cross-section X31 and X32 respectively over the Gondhia Gaon. During the predicted time interval (2019-2024), the mid-channel may shift leftward (Table 5 and Figure 7) where the highest leftward shift (725.34 metres with 145.07 $metre^{-1}$) may observe at the cross-section X17 of Bongalmora Grazing Ground and the rightward shift (1397.45 metres with 279.49 $metre^{-1}$) may visible at the cross-section X36 of Doom Gaon (Table 5 and 6).

Impact Area Assessment

Landuse/landcover (LULC) classification (Figure 8) has been generated using supervised classification with a maximum likelihood algorithm. The overall accuracy assessment were found to be 84.40%, 92.11%, 87.38%, 94.88%, 93.15% and 94.82% for the year 1973, 1978, 1989, 1999, 2009 and 2019 respectively with Kappa Coefficient of 0.7932, 0.8959, 0.8340, 0.9345, 0.9122 and 0.9312. In general, the classified images revealed an increasing trend of agricultural land and built-up area with a decreasing trend of forest cover (Table 7). During the observation period, the highest agricultural area was affected during 1989-1999 with the area of 8.7612 km^2 (0.8761 km^2/year) followed by 2.6741 km^2 (0.2431 km^2/year) during 1978-1989, 2.3661 km^2 (0.2366 km^2/year) during 2009-2019, 1.0784 km^2 (0.2157 km^2/ year) during 1973-1978 and 1.9670 km^2 (0.1967 km^2/year) during 1999-2009 (Table 8).Similarly, the highest forest cover was affected during 1999-2009 with an area of 2.7914 km^2 (0.2791 km^2/year) followed by 1.9102 km^2 (0.1910 km^2/year) during 1989-1999, 1.7522 km^2 (0.1593 km^2/year) during 1978-1989, 0.6187 km^2

(0.1237 km^2/year) during 1973-1978 and 0.5265 km^2 (0.0526 km^2/year) during 2009-2019. Likewise, the predictive channel of 2024 revealed that around 3.9444 km^2 (1.3119 km^2 from the right bank and 2.6325 km^2 from the left bank) of the agricultural area with a rate of 0.7889 km^2 per year and 0.7468 km^2 (0.2891 km^2 from the right bank and 0.4577 km^2 from the left bank) of forest area with a rate of 0.0747 km^2 per year may be affected by the channel migration during the time interval of 2019-2024 (Table 8).

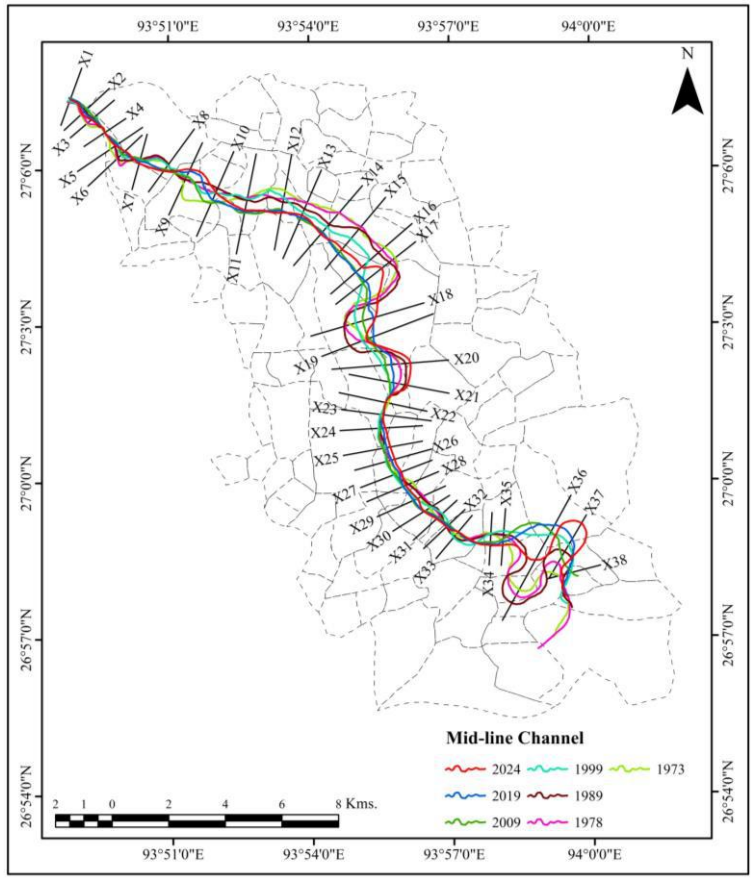

Fig. 5. Shifting of Mid-Line Channel and Future Prediction

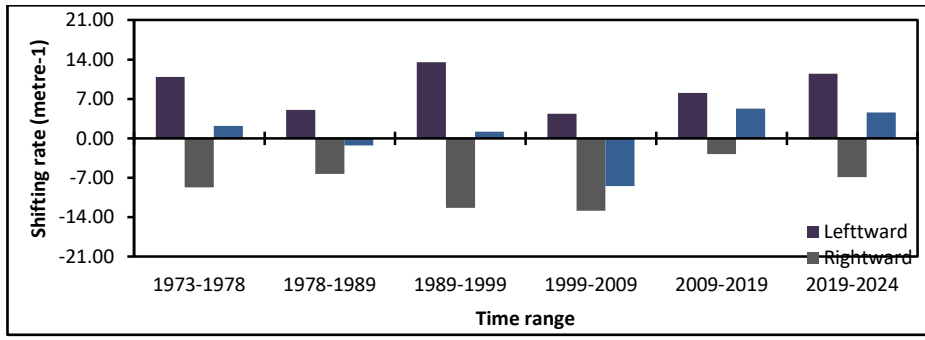

Fig. 6. Average Shifting Rate of the River Channels (metre^{-1})

Table 5. Lateral Channel Sifting and Future Prediction

Channel Shifting Based on the Year 1973					
Cross Section	1978	1989	1999	2009	2019
X1	7.61	41.84	50.63	168.54	142.31
X2	31.17	231.00	302.15	266.96	151.18
X3	42.37	303.44	357.67	355.55	263.19
X4	-14.31	-3.12	-20.46	-8.88	-14.63
X5	181.12	204.35	318.76	307.93	298.20
X6	29.95	73.55	225.90	262.82	379.22
X7	46.09	17.28	11.52	49.83	-40.09
X8	-25.65	7.31	-23.87	-184.89	-250.38
X9	171.35	148.54	295.88	262.58	461.53
X10	312.79	497.30	327.34	-72.01	51.91
X11	13.62	-73.23	-27.28	-536.91	-490.13
X12	-274.18	-397.59	-250.82	-689.78	-703.88
X13	-4.95	-223.91	-360.61	-613.22	-565.37
X14	37.61	-516.92	-645.06	-873.93	-898.64
X15	77.48	-23.78	-477.17	-1071.18	-1169.87
X16	-128.75	-290.76	-802.73	-1328.97	-1350.60
X17	-131.79	-253.18	-1459.20	-1442.39	-1343.39
X18	-172.54	-212.14	196.69	472.35	855.71
X19	-139.19	-584.48	-110.46	139.90	305.04
X20	-25.21	212.28	-610.04	-500.61	-296.82
X21	-18.90	214.26	-318.44	-347.31	-194.57
X22	-92.86	-98.04	-106.79	-92.43	-95.61
X23	-36.46	-56.28	-52.83	55.58	62.25
X24	18.55	73.25	6.15	85.80	143.57
X25	-25.35	-53.68	-42.74	-86.41	62.88
X26	116.38	-16.69	-55.58	-18.52	134.94
X27	83.02	-89.33	-129.02	-69.46	64.21
X28	-168.05	-165.30	-385.33	-350.01	-369.07
X29	78.47	14.25	-178.66	-311.27	-273.45
X30	93.09	120.79	62.99	-183.23	-244.39
X31	100.29	162.86	222.56	39.13	-11.58
X32	-38.63	-23.31	31.74	95.01	41.74
X33	-106.64	-90.99	-137.94	93.38	101.88
X34	-28.34	-34.97	-12.00	-308.22	-373.76
X35	181.38	208.35	340.44	72.38	-26.97
X36	-223.07	-538.56	2216.22	2345.78	2600.78
X37	385.61	864.03	1153.82	661.16	1382.15
X38	66.70	238.40	423.43	466.46	326.00

('+' represents left bank and '-' represents right bank)

Table 6. Rate of Lateral Mid-Line Shifting Between Two Consecutive Years (metre year^{-1})

Cross Section	1973-1978	1978-1989	1989-1999	1999-2009	2009-2019
X1	1.52	3.11	0.88	11.79	-2.62
X2	6.23	18.17	7.11	-3.52	-11.58
X3	8.47	23.73	5.42	-0.21	-9.24
X4	-2.86	1.02	-1.73	1.16	-0.57
X5	36.22	2.11	11.44	-1.08	-0.97
X6	5.99	3.96	15.23	3.69	11.64
X7	9.22	-2.62	-0.58	3.83	-8.99
X8	-5.13	3.00	-3.12	-16.10	-6.55
X9	34.27	-2.07	14.73	-3.33	19.90
X10	62.56	16.77	-17.00	-39.93	12.39
X11	2.72	-7.90	4.60	-50.96	4.68
X12	-54.84	-11.22	14.68	-43.90	-1.41
X13	-0.99	-19.91	-13.67	-25.26	4.79
X14	7.52	-50.41	-12.81	-22.89	-2.47
X15	15.50	-9.21	-45.34	-59.40	-9.87
X16	-25.75	-14.73	-51.20	-52.62	-2.16
X17	-26.36	-11.04	-120.60	1.68	9.90
X18	-34.51	-3.60	40.88	27.57	38.34
X19	-27.84	-40.48	47.40	25.04	16.51
X20	-5.04	21.59	-82.23	10.94	20.38
X21	-3.78	21.20	-53.27	-2.89	15.27
X22	-18.57	-0.47	-0.87	1.44	-0.32
X23	-7.29	-1.80	0.35	10.84	0.67
X24	3.71	4.97	-6.71	7.96	5.78
X25	-5.07	-2.58	1.09	-4.37	14.93
X26	23.28	-12.10	-3.89	3.71	15.35
X27	16.60	-15.67	-3.97	5.96	13.37
X28	-33.61	0.25	-22.00	3.53	-1.91
X29	15.69	-5.84	-19.29	-13.26	3.78
X30	18.62	2.52	-5.78	-24.62	-6.12
X31	20.06	5.69	5.97	-18.34	-5.07
X32	-7.73	1.39	5.51	6.33	-5.33
X33	-21.33	1.42	-4.69	23.13	0.85
X34	-5.67	-0.60	2.30	-29.62	-6.55
X35	36.28	2.45	13.21	-26.81	-9.94
X36	-44.61	-28.68	275.48	12.96	25.50
X37	77.12	43.49	28.98	-49.27	72.10
X38	13.34	15.61	18.50	4.30	-14.05

('+' represents left bank and '-' represents right bank)

Table 7. Landuse/Landcover of the Study Area (in km^2)

Class	1973	1978	1989	1999	2009	2019
Agriculture	117.677	142.656	156.707	129.842	168.657	169.774
Forest	83.753	80.037	61.491	79.983	55.096	45.333
Water	23.763	18.471	17.345	17.815	17.970	15.724
Sand Bank	35.434	19.390	25.042	32.555	18.215	28.563
Built-up	0.242	0.315	0.284	0.674	0.931	1.475

Table 8. Impact Area (in km^2)

Time Range	Agriculture			Forest		
	Right bank	Left bank	Total	Right bank	Left bank	Total
1973-1978	0.4086	0.6698	1.0784	0.2353	0.3834	0.6187
1978-1989	1.5962	1.0779	2.6741	0.5557	1.1965	1.7522
1989-1999	4.7662	3.9950	8.7612	0.9925	0.9177	1.9102
1999-2009	1.2255	0.7415	1.9670	1.2261	1.5653	2.7914
2009-2019	1.0067	1.3594	2.3661	0.1419	0.3846	0.5265

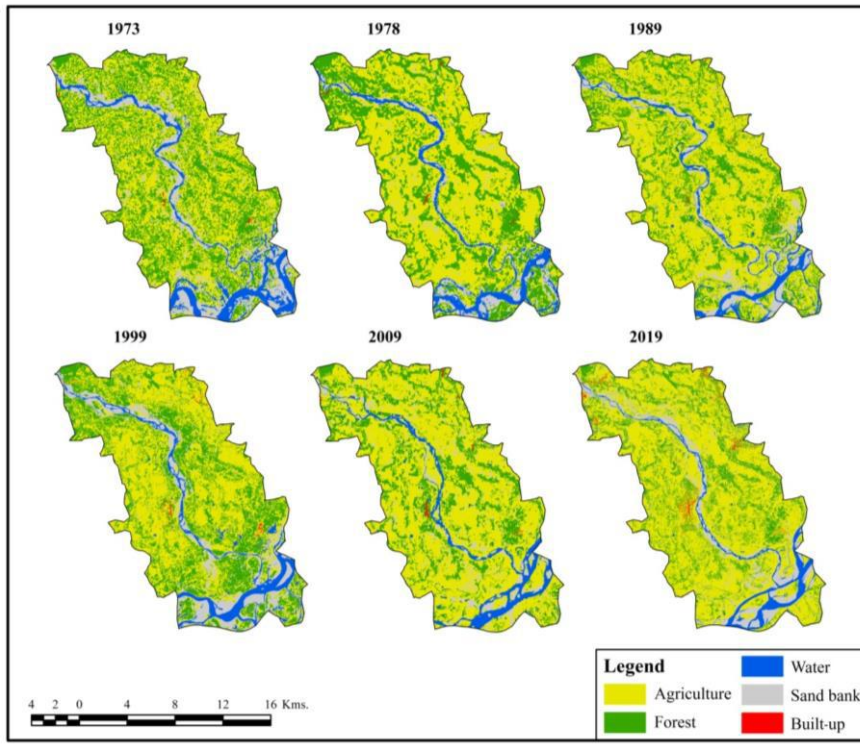

Fig. 7. LULC of the Study Area of Different Time

Various drainage morphological parameters undergo decisive changes due to massive loss to the riverbank areas (Deb and Ferreira, 2015). The mid-line channel and the respective channel width changed dramatically over the time period (1973-2019) owing to the extreme catastrophic events like floods and droughts. The present study revealed that the river Dikrong had undergone channel straightening due to meander cut-offs during the period of 1989-1999 and therefore, a huge amount of erosion and accretion was done during the time interval of 1989-1999. The result also explained by Borgohain et al., 2018 and Sah and Das (2018) where Sah and Das (2018) exposed the meandering cut-off was taken place in upper reach during 1990-1991 and near its confluence in 1993. This process of channel straightening was continued till the period of 1999-2009 where a huge deposition was recorded over the left bank. The lowest channel length (29.48 km) was recorded in 2009 which may be due to the floods of 2004 which further reduced channel length and altered the confluence with the Subansiri River. The river demonstrates a noticeable decrease in sinuosity index. However, the river has a narrower channel than its valley size, the present study found an increasing trend of the horizontal size of the active channel during the time interval of 1973-2019. During 1973-2019, a massive channel shifting occurred over the two parts of the channel. The part one was situated at the cross-section from X10 to X20 and part two was situated at the cross-section from X35 to X38. During this process of channel shifting, part one area gradually affected the villages of Parbatipur No. 1, Merbeel Gt. No. 81/78, MerbeelDighali, Pithaguri No. 5, Merbeel, Holmari Grant No. 65/68, Holmari No. 79/87 Nlr, Bongalmara Grazing Ground, Bongo Gaon, Parbatipur, Gerelua and MornoiGaon. Likewise, part two affected the villages of Pokadol Grant, Modhupur, Doom Gaon, Nahoroni, Madhupur No. 2, Dahghoria No. 1, Dahghoria Block and Dahghoria No. 2. During 1973-2019, the channel shifting has affected an area of around 24.45 km^2 of agricultural and forest area. Due to lateral migration of the channel, a huge portion of inhabitants is facing various problems related to land degradation and land loss. Along with the land loss, the inhabitants living over the confluence zone where the channel migration remains more vulnerable are also facing a huge problem of the flood, especially during the monsoon period.

Conclusion

In the present study, the bank erosions and resultant channel dynamics of the Dikrong river were studied using geospatial techniques. The analysis of remote sensing data for the period of 46 years (1973-2019) indicates a spatial and temporal variation in bank erosion and channel migration. During the time span of 1973-2019, around 24.45 km^2 of agricultural and forest area got eroded due to lateral channel migration. The partial observation over riverbank erosion and channel migration of different time interval reveals that the river is moving towards the west with an intention of channel straightness. The predictive assessment of riverbank erosion using a non-linear regression model represents a satisfactory result and highlights an area of around 4.69 km^2 of agriculture and forest cover may lose due to bank erosion. Besides, the study also exhibits the potential of Remote Sensing and GIS for immediate assessment of bank erosion and channel migration. Thus, the study can be applied for the concerned authority to take suitable mitigation measures and helps to prepare for river management strategies in future.

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News and Notes

NATIONAL ONLINE MEET ON
DEVELOPMENT OF GEOGRAPHICAL INSTITUTIONS IN INDIA - A REPORT

The Indian Geographical Society (IGS), the oldest Geographical Society in India, hosted a national level online Meet to discuss various issues and prospects for sustainable development of geographical institutions of India from 4th to 7th of September, 2020, with a support from the Geography Departments of University of Madras, Bharathidasan University and Central University of Tamil Nadu.

Indian geography is growing slowly but steadily over the past one hundred years of its existence in the country. There are a number of geography associations in the country, some are very old and some relatively new. These regional and national level geographical institutions have limited inter and intra-level networks between them. There are equally a sizeable number of journals published by these institutions in geography and allied fields, but only a few are indexed in reputed databases. Under these circumstances, the Indian Geographical Society hosted a national level online Meet as a pre-centenary celebration event, to discuss the issues and prospects for symbiotic development of all geographical institutions and their publications, keeping in view the dynamic nature of the discipline.

The circular of the Meet was widely circulated to more than 50 geographical institutions of India and representatives of the respective institutions were requested to present their activities during the Meet. In addition, the background of Meet was circulated through email and social media to the geography fraternity for participation. The Society had received overwhelming response of 836 individual registrations. To accommodate more number of participants, the event was hosted through Cisco Webex platform.

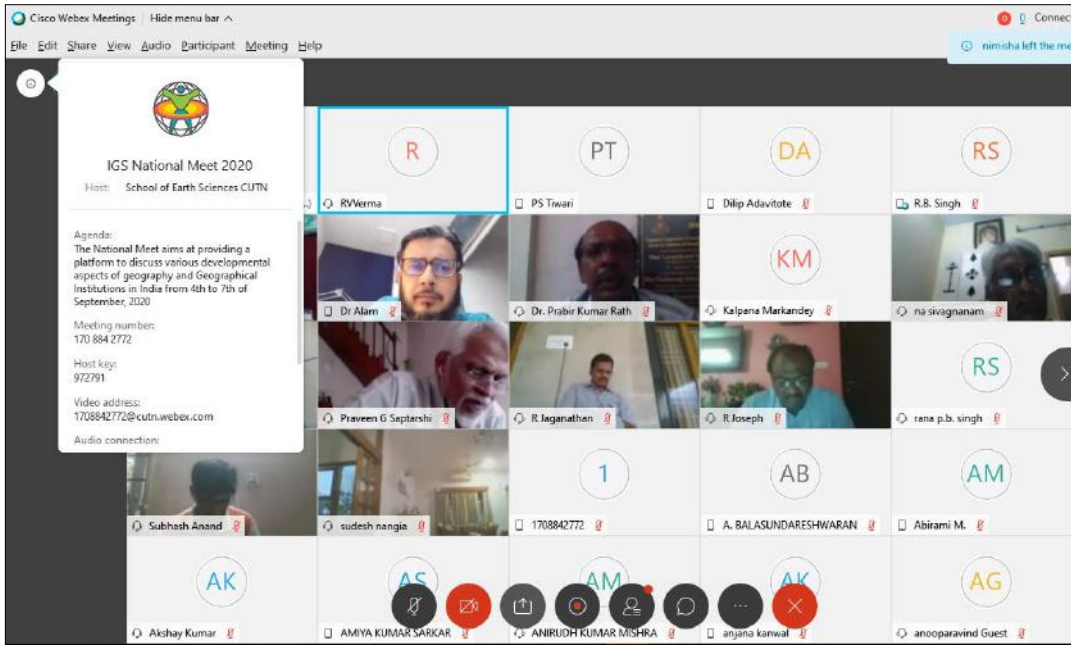
The Meet was scheduled under seven sessions followed by a panel discussion. The Meet received willingness from 29 geographical institutions from various parts of India (Table 1). All the institutions presented their activities in the Meet and the event was attended by more than 400 participants all over India and neighbouring countries. The Meet was inaugurated by Prof. R. B. Singh, Secretary General and Treasurer, the International Geographical Union (IGU) and Prof. N. Sivagnanam, President of the Indian Geographical Society.

In addition to the institutional presentations, special lectures by senior/eminent geographers of India were also arranged. They were invited for chairing the sessions and deliver special lectures. A panel discussion was also arranged on the last day of the Meet

with the chairpersons of the sessions and senior members like Prof. R. B. Singh, Prof. N. Sivagnanam, Prof. Sudesh Nangia, Prof. K. Nageswara Rao, Prof. R. V. Verma, Prof. Surya Kant, Prof. G. K. Panda, Prof. K. Kumaraswamy, Prof. Kalpana Markandey, Prof. Praveen G. Saptarshi, Prof. Rana P.B. Singh, Prof. Krishna Mohan, Prof. Prithvish Nag, Prof. V. P. Sati, Prof. Biplab Biswas, Dr. Arun Kumar Singh and Prof. R. Jaganathan.

Table 1. List of Participated Geographical Institutions of India during the Meet

Sl.	Session	Institution	Presenter
1	I	The Indian Geographical Society, Chennai	Prof. K. Kumaraswamy
2	I	Association of Geography Teachers of India, Chennai	Dr. R. Saraswathi
3	I	Union of Geographic Information Technologists, Bengaluru	Prof. Ashok Hanjagi
4	I	Kerala Geographical Society, Palakkad	Prof. P. K. Vijayan
5	II	Maharashtra Bhugolshastra Parishad, Pune	Prof. Praveen G. Saptarshi and Dr. C. Jyotiram More
6	II	The Bombay Geographical Association, Mumbai	Prof. SV Chawan, Prof. V.S. Phadke, and Prof. B.B. Sonule
7	II	Geographers Association Goa, Goa	Dr. Prabir Kumar Rath
8	II	Karnataka Geographers Association, Bagakot	Dr. Siddharam S. Hangaragi
9	II	Telengana Geographical Society, Hyderabad	Dr. R. Sudhakar Goud
10	II	Solapur Bhoogol Shikshak Sangh, Solapur	Dr. S.C. Advitot and Dr. Harishchandra B. Tipe
11	III	The Society of Geographers, Jabalpur	Dr. Lokesh Shrivastava
12	III	Rayalaseema Geographical Association, Tirupati	Dr. N. Chendrayudu
13	III	National Geographical Society of India, Varanasi	Prof. Rana P.B. Singh
14	IV	Association of Population Geographers of India, Chandigarh	Prof. Krishna Mohan and Prof. Surya Kant
15	IV	Association of Punjab Geographers, Patiala	Prof. H. S. Mangat and Dr. Lakhvir Singh Gill
16	IV	Konkan Geographers Association of India, Sindhudurg	Dr Rajaram Patil and Dr Shivam Thakur
17	V	Eastern Geographical Society, Bhubaneswar	Prof. G.K.Panda
18	V	Indian Council of Geographers, Patna	Prof. G.K.Panda
19	V	Association of Bengal Geographers, Burdwan	Prof. Narayan Chandra Jana
20	V	Indian Society of Spatial Scientists, Kolkata	Dr. Priyank Pravin Patel
21	V	Geographical Association of Mizoram, Aizawl	Prof. Vishwambhar Prasad Sati
22	VI	Foundation of Practicing Geographer, Kolkatta	Dr Arun Kumar Singh
23	VI	The Association of Geographical Studies, Delhi	Dr. Amrita Bajaj
24	VI	Environmental Monitoring Society, Delhi	Prof. T. S. Rana
25	VII	Association of Professional Geographers, Delhi	Prof. Prithvish Nag
26	VII	Association of Geographers in Bihar and Jharkhand, Patna	Prof. Devendra Prasad Singh and Dr. Vikrant Kumar
27	VII	Geographical Society of Arunachal Pradesh, Itanagar	Dr. Tage Rupa Sora
28	VII	GeoMap Society, Hyderabad	Dr. V. Raghavaswamy
29	VII	IGU-India, New Delhi	Dr. Subhash Anand and Dr. Gaurav Sikka



The Snapshot of the National Meet held on 4-7 September, 2020

The deliberations made by senior/eminent geographers during the interactive sessions and panel discussion were very fruitful for symbiotic development of various Geographical Institutions in India. The following are the major resolutions passed in the Panel Discussion of the Meet to send them to appropriate forums for redresses/actions.

1. Restore the health of journals and also network of journals in geography (especially to filter down the criteria for inclusion of journals in UGC). The journals in UGC-CARE list should be divided into different levels (Schools, UG/PG level study and R&D). This will help geographers to cover the journals at appropriate levels.

2. Geography subject should be a compulsory one at all levels of educational system. Quality of geography should be improved and it should be treated as a separate subject at school level. The subject is to be taught exclusively by geography teachers. The syllabi of Schools and Colleges should be strengthened. Parents and school students should be sensitised widely to opt geography at higher level studies.

3. Specific posts in Public Sectors/Services should be marked only for geographers. National Commission of Geographical Information under the Ministry of Earth Sciences should be constituted. Geographers should represent in the institutes of ISRO, School of Planning, National Institute of Disaster Management (NIDM), and all other spatial data user institutions.

4. The subject of geography should be considered under Faculty of Sciences rather than Arts for better consideration and employment opportunities. Courses like communication and soft skills, project management, data science etc. should be incorporated in both UG and PG level studies for creating better employment

opportunity to the geography students. Geography learning through regional languages should be encouraged at all levels.

5. Curriculum should be improved in the light of the National Educational Policy - 2020 to accommodate graduate study of 4 years. Geography is not only arts, science but also technology. Hence, B.Tech/M.Tech programmes in Geography should be introduced in IITs, NITs etc. Geography discipline should be accommodated in GATE.

6. Steps may be taken to invite International Geographical Union (IGU) Meeting to India. It was lastly held in 1968 (50 years back). Steps need to be taken to reduce the life membership fee in various geography institutions, which would help joining many students in geographical associations.

7. Initiate steps to establish National Institute of Geography or Indian Council of Geographical Research (ICGR) for which a committee should be constituted at the earliest. Commissions on Sustainability Management should be constituted to revisit issues in the sectors of agriculture, mining, manufacturing and services.

8. Capacity development programmes should be arranged for geographers to improve the standard of their research proposals. A repository is to be created for geography teachers. Further, skill development programmes should be conducted for students for better employability. Financial support is to be explored for young geographers to conduct innovative research in geography.

9. Self-retrospection is needed for survival of geography in India. The roots of Indian geography need to be examined and the cultural roots should be explored. Cultural geography should be given due emphasis in UG and PG programmes.

10. Indian Council of Geographers needs to be revived. National unity is the key to achieve linking the national societies and for international recognition. For example, Association of American Geographers, where in all geographical institutes are united under one single forum for representing geography to evolve national policies. This forum should act as a coordinating and representative body for all institutions and to raise the issues of geography at national and regional levels.

11. Social media channels like Facebook, Twitter etc. would be widely used to disseminate geographic news and events.

12. Analytical thinking should be incorporated in the content of geography. Incorporation of geographic modelling, mathematics, statistics, artificial intelligence etc. in appropriate curriculum would help geographers to take part the competitive examinations confidently.

The recorded sessions of the event are hosted in the IGS website (www.igschennai.org). The programme was widely appreciated and received appreciable feedback from the participants and it sets a landmark for organising such meets in the future.

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News and Notes

THE INDIAN GEOGRAPHICAL SOCIETY

Department of Geography, University of Madras, Chennai - 600 025

Conduct of 11th Talent Test - 2021 for Geography Students

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The conduct of State wide **Eleventh Talent Test - 2021** for final year UG and PG students of the Geography Departments in Tamil Nadu is **postponed to the end of current academic year (April/May, 2021), due to prevalence of Covid-19 outbreak**.

The IGS Founder Prof. N. Subrahmanyam Award

for final year UG students

&

Prof. A. Ramesh Award

for final year PG students.

General Information

1. Talent Test **will be conducted in English language only for PG students and in English and Tamil for UG students**.
2. Syllabi for UG and PG talent tests are UGC NET Paper II & III respectively.
3. Final year UG and PG students of Geography are eligible for Talent Test.

Please visit IGS website (http://www.igschennai.org) for the exact date, modalities and other details.

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I, K. Kumaraswamy, hereby declare that the particulars given above are true to the best of my knowledge and belief.

Dr. K. Kumaraswamy
Editor, The Indian Geographical Journal