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Research Article

DELINEATION OF SHIVALIKS IN EASTERN AND NORTH-EASTERN REGION OF INDIA USING MODERN GIS TECHNIQUES

VIKAS*, YADAV R.P., SURYA J.N., MEENA R.K. AND ASHOK KUMAR
ICAR-National Bureau of Soil Survey & Land Use Planning, Regional Centre Delhi, 110 012, India
*Corresponding Author: Email - vikashhau@gmail.com

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Abstract: Eastern and north-eastern Shivalik region occurs in states of West Bengal, Assam and Arunachal Pradesh in India and is least studied among Shivalik regions of the world. There is no specific study no its area and distribution in the region. An attempt has been made to delineate the Shivalik region in eastern and north-eastern region of the country using geological and physiographical maps, soil maps and remote sensing data using GIS tools. Total area of Shivalik region (1.50mha) comprises of 0.75mha under hills and 0.75mha under piedmont plains or foot hills. The region demarcated in the states of West Bengal, Assam and Arunachal Pradesh is found at elevation ranging from 51 to 1928 m above MSL. The first estimate on the Shivaliks in this part of the country will prove very useful in prioritizing resource conservation and policy intervention by the central and state governments as Shivalik is one of the most vulnerable zones of India.

Keywords: *Shivalik, Eastern and North-Eastern region, West Bengal, Assam, Arunachal Pradesh, GIS*

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Introduction

Eastern Himalayas, covering eastern and north-eastern states of India, is a land of undulating hills and plains with rich biodiversity. These mountains and hills are characterized by landslides, steep slopes, severe erosion, high rainfall and poor socio-economic conditions than plains. Physio-graphically, this region can be classified into eastern Himalaya, Patkai, Brahmaputra and the Barak valley plains. The main Himalaya is divided into four morpho-tectonic belts each with peculiar lithological features. Shivalik ranges are described as youngest mountain and sub-mountainous ranges running parallel to Himalayan Mountain on southern side and extends across border through Nepal and Pakistan [1].

This region has a predominantly humid sub-tropical climate with hot, humid summers, severe monsoons, and mild winters. The two-thirds area of the region is hilly terrain interspersed with valleys and plains; the altitude varies from almost sea-level to over 7,000 mabove MSL. The Shivalik range in eastern and north-eastern region is spread in patches and varied in its reporting. The Shivalik system in the Darjeeling hill areas is comprised of mudstones, sandstones, shale and conglomerates along with the bands of shale and lignite.

In the Hill Cart Road and along the Tista River a few stretches of good exposes of Shivalik are found. The general strike of these rocks is North-North East (NNE)-South-South West (SSW) to North West (NW)-South East (SE) with dips varying between 30º to 60º. Previous studies from eastern Himalayas reported evidences of Shivalik hills in Assam [2], Arunachal Pradesh [3,4] and West Bengal [5].

Natural resources endowed eastern Himalayas, are susceptible to landslide, soil erosion, faulty agriculture practices, water availability, biodiversity loss and so on [6]. The geology of Itanagar Capital Complex of Arunachal Pradesh constitutes mainly Shivalik sediments and unconsolidated Quaternary deposits. The Shivalik sediments are represented by Dafla, Subansiri and Kimin formations belonging to the Middle Shivalik [7]. In the Kameng District of Arunachal Pradesh, three subdivisions of Shivalik, *viz*, lower, middle and upper are exposed in reverse stratigraphic order. A rich assemblage of plant fossils is present in the Shivalik group of rocks. The mega plant remains including one leaf compression and cuticular fragment from the upper Shivalik of the West Kameng district have been described [8]. Shivalik region is well demarcated in north-western India [9,10] but such demarcation is lacking in north-eastern and eastern India.

Keeping this in view, the present study was taken to delineate the Shivalik range in eastern Himalayan region and delineate hills and piedmont plain in the eastern and north-eastern Shivalik region. This will provide valuable information for diverting financial resources towards target area rather than spread across the hill region for development and conservation initiatives.

Materials and Methods

Study Area

The study carried out in north-eastern and eastern states of India covering eight and one states, respectively. Out of these, only West Bengal, Assam and Arunachal Pradesh is Shivalik region and were taken for delineation of Shivalik hills and associated piedmont plains. The total geographical area (TGA) of West Bengal, Assam and Arunachal Pradesh are 88752, 78438 and 83743 sq. km, respectively. There is no prior information about the area and extent of occurrence of Shivalik area in these states. Lack of the information on the area and its delineation has been hindrance for planners to take projects for their rehabilitation has been done extensively in the north-western region of the country.

Maps and Software used

Administrative map of West Bengal [11], geographical maps of Assam (on 1:1 million scale) and Arunachal Pradesh (on 1:750,000 scale) [12,13], geological map (on 1:1 million scale) of the eastern and north-eastern Himalayan region [14] and soil maps (on 1:5,00,000 scale) of West Bengal, Assam and Arunachal Pradesh [15-17] developed for administrative, development and conservation planning were used. The Arc-GIS (10.3.1) software was used for delineation and statistical calculations of the study area.

Delineation of Shivalik Hills and Piedmont Region

The earlier methodology applied in north-western region for delineation of Shivalik region was employed in this study [Yadav *et al*., 2015].

Table-1 *Distribution of Shivalik region under different states of Eastern and North-eastern India*

SN	State	District	Latitude and Longitude	Area (000 ha)	(% of TGA of state)
1	West Bengal	Darjeeling, Jalpaiguri, Kalimpong and Alipurduar	26°38'39'' to 26°59'10'' N 88°10'46'' to 89°52'47'' E	89	1
2	Assam	Kokrajhar, Chirang, Baksa, Udalguri, Sonitpur, Lakhimpur, Dhemaji, Tinsukia, Dibrugarh and Slbsagar	26°10'20'' to 27°48'45'' N 89°53'51'' to 96°03'07'' E	745	9.5
3	Arunachal Pradesh	Bomdila, Seppa, Itanagar, Ziro, Aalo, Pasighat, Tezu, Khonsa and Changlang	26°53'16'' to 28°14'03''N 92°10'56'' to 97°10'36'' E	676	8.08
Total				1510	

Table-2 *Area, elevation and range of spread of Shivalik Hills region in different states*

SN	State	Elevation (m above MSL)		Range of spread/Geographical Spreads		Area (sq. km)	No. of district	District name
		Min.	Max.	Latitude	Longitude			
1	West Bengal	175 m	1159 m	26°40'56"N	88°10'41" E	233.94	4	Darjeeling, Jalpaiguri, Kalimpong and Alipurduar
				27°00'17" N	89°49'43" E			
2	Assam	90 m	1003 m	26°42'52" N	89°51'59" E	919.39	7	Kokrajhar, Chirang, Baksa, Udalguri, Sonitpur, Lakhimpur and Dhemaji
				27°51'16"N	95°15'42" E			
3	Arunachal Pradesh	128 m	1928 m	26°53'12" N	92°07'11" E	6374.75	9	Bomdila, Seppa, Itanagar, Ziro, Aalo, Pasighat, Tezu, Khonsa and Changlang
				28°02'06"N	97°07'31" E			

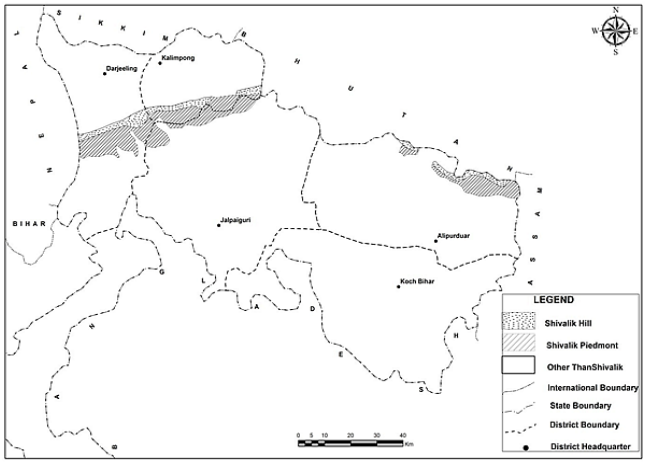

Fig-1 Map of Shivalik region in West Bengal.

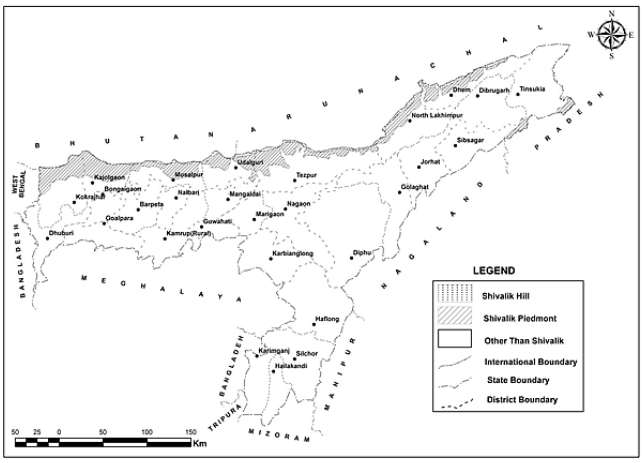

Fig-2 Map of Shivalik region in Assam.

The Shivalik region was delineated by using various maps. From the Shivalik region, Shivalik hills and their piedmont plains were demarcated based on published geological and soil maps of the study area. The geological formations of the eastern and north-eastern Himalayan region were derived from geological map and used to demarcate the Shivalik hills. The mapping unit NQ1 (Pliocene-Miocene) was determined from the map as Shivalik hills.

Piedmont region under the Shivalik hills are transitional areas between Shivalik hills and plains. This area was demarcated from soil maps of West Bengal and Assam and piedmont plain of Arunachal Pradesh was mapped with the help of unit Pg3 given in geological map of the eastern and north-eastern Himalayan region. These maps were reduced to the same scale (1:1 million scale) and traced. Area under piedmont plain was superimposed on administrative map of West Bengal, geographical maps of Assam and Arunachal Pradesh.

The district boundaries were overlaid on Shivalik region maps by using geographical or political maps of the states and base map of region were brought to 1:1 million in GIS environment by using Arc-GIS (10.3.1) software. From this base map, latitude and longitude values and the range of elevation difference in the Shivalik region in different states was determined in Arc-GIS software. Overall values for the entire region in eastern and north-eastern part of the country were deduced from the state values for extent and occurrence. Area under Shivalik hills and piedmont plains was calculated in Arc-GIS software on 1:1 million scale state maps and combined for the whole region.

Results

The map of Shivalik region of eastern Himalayas has been prepared by using published geology, physiography and soil maps in the different states. The results are shown under.

Shivalik Region in Eastern and North-eastern India

The area under Shivalik region in different districts in north-eastern region of India was delineated [Fig-1 to 3]. Elevation difference and geographical occurrence in the states was also established [Table-2 & 3]. Shivalik region, located between 26°10'20'' to 28°14'03''N latitudes and 88°10'46'' to 97°10'36'' E longitudes in north-eastern part of India, forms a long and narrow stretch from West Bengal to Assam and Arunachal Pradesh [Fig- 4]. Its elevation ranges from 90 to 1928 m and 51 to 1548 m above MSL in hills and piedmont respectively. The lowest ranges of hills located in Assam (90 to 1003 m above MSL) while Arunachal Pradesh has highest ranges of Shivalik hills (128 to 1928 m above MSL). Also, in Shivalik piedmont the lowest ranges found in Assam (51 to 515 m above MSL) while Arunachal Pradesh has the highest ranges (160 to 1548 m above MSL). The Shivalik region comprising of Shivalik hills and piedmont plains covers 1.50 mha area [Table-4] which constitutes 18.58 per cent of total area of selected states of the region. Among the states, maximum area is delineated in Assam (0.74 mha) followed by Arunachal Pradesh (0.68 mha) and West Bengal (0.08 mha). And also, per cent of total geographical area is highest in Assam (9.50%) followed by Arunachal Pradesh (8.08%) and West Bengal (1.00%). Out of total area of Shivalik region (1.50 mha), 0.75 mha is under hills and 0.75 mha under piedmont plains [Table-4]. Arunachal Pradesh has higher area under hills while Assam has predominance of piedmont plains followed by West Bengal.

Discussion

Shivalik Region in Different States

Geographical spread of Shivalik hills and piedmont plains in eastern and north-eastern region of India has demarcated on the bases of the published literature and remote sensing data using modern techniques of mapping.

Table-3 *Area, elevation and range of spread of Piedmont region in different states*

SNo	State	Elevation (m above MSL)		Range of spread / Geographical Spreads		Area (sq.km.)	No. of districts	District name
		Min.	Max.	Latitude	Longitude			
1	West Bengal	91m	841 m	26°35'50"N	88°11'23" E	662.47	4	Darjeeling, Jalpaiguri, Kalimpong and AlipurDuar
				26°59'54" N	89°52'15" E			
2	Assam	51 m	515 m	26°25'20" N	89°51'48" E	6532.5	10	Kokrajhar, Chirang, Baksa, Udalguri, Sonitpur, Lakhimpur, Dhemaji, Tinsukia, Dibrugarh and Slbsagar.
				27°49'42"N	96°01'53" E			
3	Arunachal Pradesh	160 m	1548 m	27°15'53" N	95°55'06" E	394.89	2	Changlang and Tezu
				27°34'53"N	96°56'23" E			

Table-4 *Area under Shivalik region and its distribution under hill and piedmont in different States of Eastern and North-eastern India*

SNo	State	Area (000 ha)			Area (mha)			% Area of State		
		Hill	Piedmont	Total	Hill	Piedmont	Total	Hill	Piedmont	Total
1	West Bengal	23	66	89	0.02	0.06	0.08	0.26	0.74	1
2	Assam	92	653	745	0.09	0.65	0.74	1.17	8.33	9.5
3	Arunachal Pradesh	637	39	676	0.64	0.04	0.68	7.61	0.47	8.08
Total		752	758	1510	0.75	0.75	1.5	9.04	9.54	18.58

**ha- hectare, *mha- Million hectare*

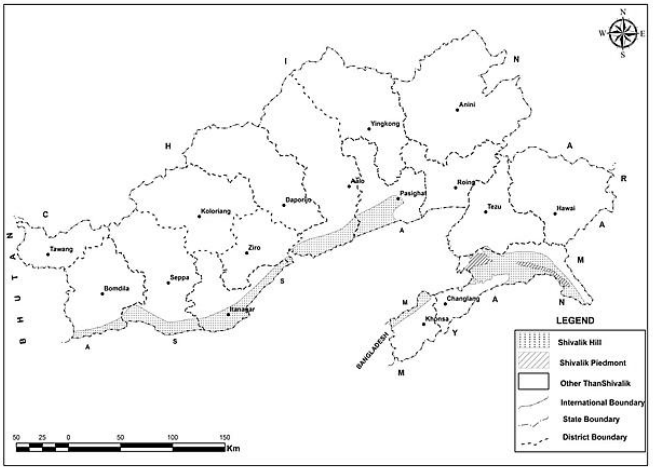

Fig-3 Map of Shivalik region in Arunachal Pradesh.

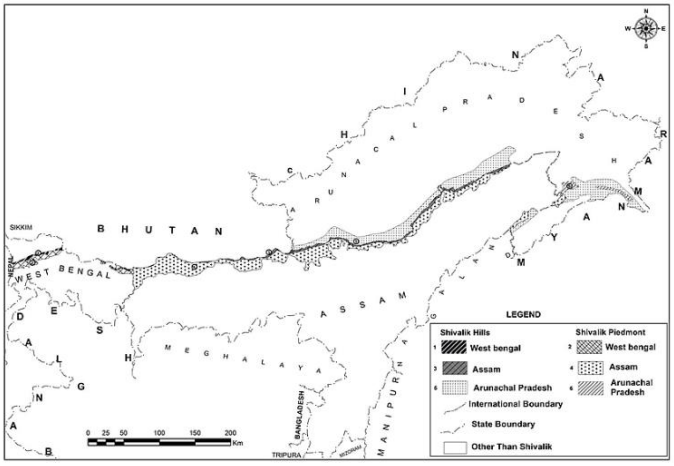

Fig-4 Map of Shivalik region in Eastern and North-eastern India.

There is no any evidence available in any research article or literature about the area under Shivalik region in this part of India. However, the existence of the Shivalik region in eastern and north-eastern India is an established fact. Literature on studies of different aspects of Shivalik has been compiled and utilized to delineate the region scientifically taking geology, slope, land uses etc. in the consideration. Basic studies in the literature formed rationale for exclusion or inclusion of an area in the Shivalik region. The area so delineated in different states of this region of India is discussed below.

West Bengal

The extension of Shivalik region lies between 26°38'39" to 26°59'10" N latitudes and 88°10'46" to 89°52'47" E longitudes in this state [Table-1]. The Shivalik hill and piedmont region covers an area of 233.94 and 662.47 sq. km respectively which is 1.00% area of the state [Table-2 to 4]. The Shivaliks passes through the different parts of Darjeeling, Kalimpong, Jalpaiguri and Alipurduar districts [Fig- 1]. Shivalik region in the state occur at elevation ranging from 91 to 1159 m above MSL. Earlier study has shown that the Shivalik group of rocks extends in its strike direction for more than 1,500 km from north-west of Jammu to south of Darjeeling [18], but not given any idea about the area of Shivalik region in West Bengal state.

Assam

In this state, the extension of Shivalik region lies between 26°10'20" to 27°48'45" N latitudes and 89°53'51" to 96°03'07" E longitudes [Table-1]. The Shivalik region in Assam covers an area of 919.39 and 6532.50 sq. km under hill and piedmont plains, respectively which is 9.50% of the TGA of the state [Table-2 to 4]. The area of the Shivalik region passes through the upper portion of the state and has distribution in the districts of Kokrajhar, Chirang, Baksa, Udalguri, Sonitpur, Lakhimpur, Dhemaji, Tinsukia, Dibrugarh and Slbsagar [Fig-2]. The elevation ranges from 51 to 1003 m above MSL. This region was delineated in different districts of Assam by overlaying geological map of that region on the physiographical map of the state in which district boundaries were already shown.

Arunachal Pradesh

Area under Shivalik hills and piedmont plains are 6374.75 and 394.89 sq. km respectively [Fig-3] with an extension lies between 26°53'16" to 28°14'03"N latitudes and 92°10'56" to 97°10'36" E longitudes [Table-1]. Out of the total TGA of states, Shivalik region spread over 8.08% area in the elevation range of 128 to 1928 m above MSL. Distribution of Shivalik region in the state passes through the districts of Bomdila, Seppa, Itanagar, Ziro, Aalo, Pasighat, Tezu, Khonsa and Changlang. However, the piedmont plain has seen demarcated in Changlang district and some parts of Tezu district. As per Assam, same methodology was used for delineation of Shivalik region in different districts of this state. Piedmont portion of this state was delineated from Pg3 unit of geological map. The river terraces below the hills were delineated from the google and Arc-GIS software base map and considered as Shivalik piedmont.

Shivalik Region in Eastern and North-eastern India

In eastern and north-eastern India, Shivalik region located between 26°10'20" to 28°14'03"N latitudes and 88°10'46" to 97°10'36" E longitudes forms a long and narrow stretch from West Bengal to Assam and Arunachal Pradesh [Fig- 4]. Area under Shivalik region is 1.50 mha comprising of both Shivalik hills and piedmont plains constituting 18.58 per cent of total area of three states. The present paper provides authenticate information on the area and distribution of the Shivalik as it derives the information from relevant published scientific documents or maps generated by Geological Survey of India, National Bureau of Soil Survey and Land Use Planning, Survey of India and related information from states and the literature.

The compiled information has been updated and collaborated further from remote sensing data in GIS environment leaving little scope for error. It is the first time that the maps have been prepared state wise demarcating various districts falling in the Shivalik region. The synthesized information will prove very useful to planners and policy makers in sustainable development of the region.

Conclusion

This study demarcated the geographical spread of Shivalik region under the eastern and north-eastern states of India. The Geological map of India for Shivalik hills region and NBSS&LUP published soil maps of the states for piedmont plains were used for delineation. The Shivalik region in this study area extends from 26°10'20'' to 28°14'03''N latitudes and 88°10'46'' to 97°10'36'' E longitudes at an elevation ranging from 51 to 1928 m above MSL and covers an area of 1.50 mha which constitutes 9.04 and 9.54% hills and piedmont plains respectively. The generated map of Shivalik region for eastern and north-eastern region is unique one and first in attempt. It will provide the more reliable information regarding Shivalik region in this area. It will helpful to many development agencies at various scales and to the planner. It also provides valuable inputs for prioritization of financial resources allocated under various hill development initiatives for natural resources conservation and socio-economic developmental planning.

Application of research: The synthesized information will prove very useful to planners and policy makers in sustainable development of the region. It will helpful to many development agencies at various scales and to the planner. It also provides valuable inputs for prioritization of financial resources allocated under various hill development initiatives for natural resources conservation and socio-economic developmental planning.

Research Category: Geographic information system

Abbreviations: ha-hectare, mha-Million hectare, m-metre, MSL-Mean Sea level

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Study area / Sample Collection: West Bengal, Assam, Arunachal Pradesh-Shivalik region, Shivalik hills

Cultivar / Variety / Breed name: Nil

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Ethical Committee Approval Number: Nil

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