Infrastructure development status analysis through GIS technique

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Abstract

Geographic Information System (GIS) has demonstrated itself as a very powerful tool in database management and quick decision support system. The present study proposes an empirical methodology for analyzing and mapping of physical infrastructure development assessment through GIS techniques. This study is carried out on twenty nine blocks of Paschim Medinipur district under West Bengal of India. This paper summaries multi-criteria decision approach to analyze present physical infrastructure status for block development assessment based on twenty variables, like public service facility (bank, post office, co-operative societies and primary hat), transport facility (road length, railway access and bus root), public utility service (electricity and spot source water), medical facility (hospital, health centre, clinic and veterinary hospital), education facility (Sishu Siksha Kendras/SSK, Madhyamik Siksha Kendras/MSK, primary school, institution, college and university) and public welfare (library and family welfare centre) that are mandatory inputs to infrastructure development assessment model. These parameters are obtained from satellite image, census of West Bengal, district planning office data, respectively. ArcGIS and Erdas imagine model builder/maker is used to construct the index model for infrastructure development analysis. Finally all blocks have been ranked according to the present infrastructure facility.

Keywords- Remote Sensing, GIS, Infrastructure, Index model, Multi-criteria decision approach

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1. 1 Introduction

Infrastructure is basically the foundation of a region, on which economic growth is built. Roads, water systems, mass transportation, airports, and utilities are all examples of infrastructure. It is basic physical and organizational structures, needs for the operation of a society or enterprise, or the services and facilities necessary for an economy to function (Steven 2003). It can be generally defined as the set of interconnected structural elements that provide framework supporting an entire structure of development. Infrastructure facilitates the production of goods and services, and also the distribution of finished products to markets, as well as basic social services such as schools and hospitals; for example, roads enable the transport of raw materials to a factory. In military parlance, the term refers to the buildings and permanent installations necessary for the support, redeployment, and operation of military forces (Fulmer 2009). The present study is carried out to prepare block wise different infrastructure facility map of Paschim Medinipur and thereby to determine the development status (backwardness or forwardness) by developing a multi-criteria decision support system using twenty variables, namely public service facility (bank, post office, co-operative societies and primary hat), transport facility (road length, railway access and bus root), public utility service (electricity and spot source water), medical facility (hospital, health centre, clinic and veterinary hospital), education facility (Sishu Siksha Kendras/SSK, Madhyamik Siksha Kendras/MSK, primary school, institution, college and university) and public welfare (library and family welfare centre.

2.1 Study area and materials used

Paschim Medinipur has been selected as the study area which is located between 21 $^{°}$46$^{″}$ N to 22$^{°}$ 57$^{″}$ N and 86$^{°}$ 33$^{″}$ E to 87$^{°}$ 44$^{″}$ E, and bounded on the north by Bankura and Purulia districts, on east by Purba Medinipur district, on the south by Purba Medinipur district and Balasore district

of Orissa and on the west by Mayurbhanj district of orissa and Singbhum districts of Jharkhand. The district area is represented by Survey of India topographical map nos. 73J, 73N, and 73O and the imageries IRS-ID i. e., path/row 107_56, 107_57 and 108_56. The total geographical area of Paschim Medinipur district is 9295.28 sq km. There are 29 Blocks and 4 Sub Division in Paschim Medinipore. Highest density of population is shown in Daspur blocks located in north-eastern part of districts while the lowest density is recorded in Nayagram block located in the south western part of District.

Different types of data sets are used for this study. These are (i) Digital Elevation Model (DEM): one of the most widely used DEM data sources is the elevation information provided by the Shuttle Radar Topography Mission (SRTM) (Coltelli *et al*., 1996), As with most other DEM sources, the SRTM data requires significant levels of pre-processing to ensure that there are no spurious artifacts in the data such as pits, spikes and patches of no data (Dowding *et al*., 2004) that would cause problems in later analysis. In the case of the SRTM data, these patches of no data are filled, preferably with auxiliary sources of DEM data, like-topographical maps. Both SRTM data sets and topographical map are used for this study; (ii) Optical bands with Standard False Color Combination (SFCC) of IRS-1D satellite images are used to find out the land use/land cover classes in the study area; and (iii) secondary data from Census of West Bengal. All other details of the variables are given in the Table 1.

Table 1

Different variables used for this study

Variables	Scale/resolution	Year	Source
	1:250000	1960	University of Texas Libraries, Austin
Topographical map	1:50000	1973-80	Survey of India, Kolkata
IRS-1D, LISS-III	23 m	2002	Vidyasagar University
SRTM data	3-arc seconds	2003	*ftp://e0srp01u.ecs.nasa.gv*
Census report	-	2009	District planning office, Statistical office

3.1 Methodology

ArcGIS 10.0 and Erdas Imagine software are used for the preparation of different thematic map using satellite image, topographical map, statistical report and collateral information.

3.2 Preparation land use/land cover, relief, drainage and block boundary map

The land use /land cover data sets are generated from the digital image classification of IRS-1D, LISS-III satellite images using Erdas Imagine software. This classification is performed taking seven classes within the entire study area, namely agriculture, agriculture fallow, dense forest, low dense forest, open forest, sand and wasteland (Fig. 1). Overall accuracy achieved is 91%, after the carrying out an accuracy assessment using ground truth (reference sample points) data sets.
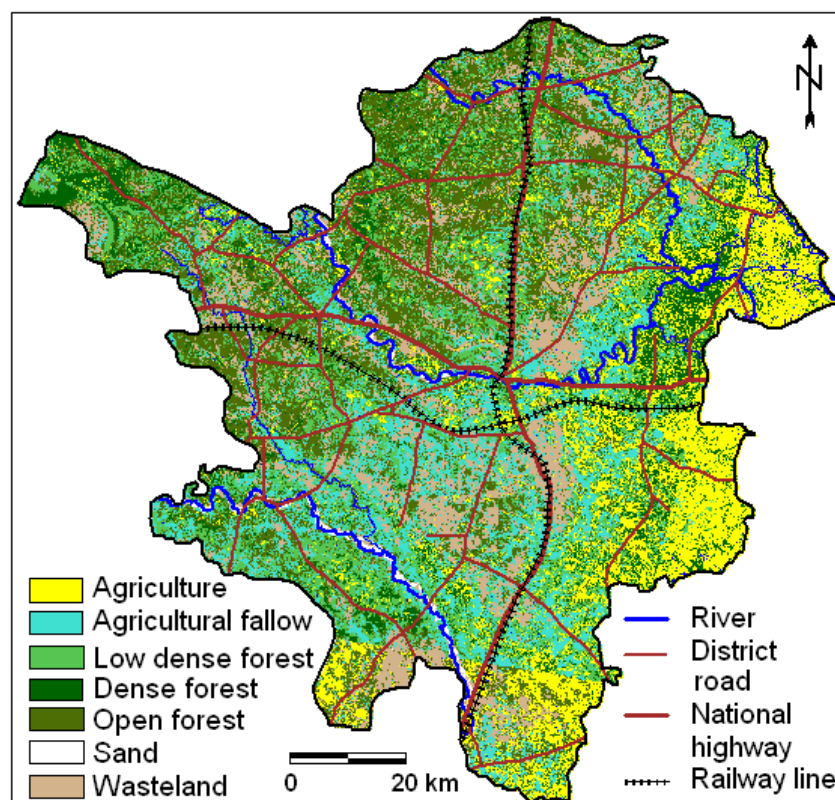

Fig. 1   Land use/land cover map of Paschim Medinipur, based on Satellite image

Drainage map is prepared using the topographical map and satellite image (Fig. 2a). The flow direction of Paschim Medinipur is from north-west to south-east. Major Rivers in Paschim Medinipur are Slilabati, Kansabati, Subarnarekha, Kaliaghai, Darakeshar and Dulung. As with most DEM data sources, the SRTM data requires significant levels of pre-processing to ensure that there are no spurious artifacts in the data that would cause problems in later analysis such as pits, spikes and patches of no data (Dowding *et al.* 2004; Gamache, 2004; Fisher and Tate, 2006). In the case of SRTM data, these patches of no data are pervasive and filled with auxiliary sources of DEM data, like topographical maps. The study area recorded a maximum elevation of 319 meter which is observed at the north-west part of the study area (Fig. 2b), having several hills of irregular shapes appeared as the tableland of Chotonagpur rolls down. There are 29 Blocks and 4 Sub Division in Paschim Medinipur. In the ArcGIS software is used to digitize all the block boundary of Paschim Medinipur. Block names are given into the attribute table to identify the each block at the time of spatial query from data base. The block boundary map is prepared with their name displayed on the map (Fig. 2a).
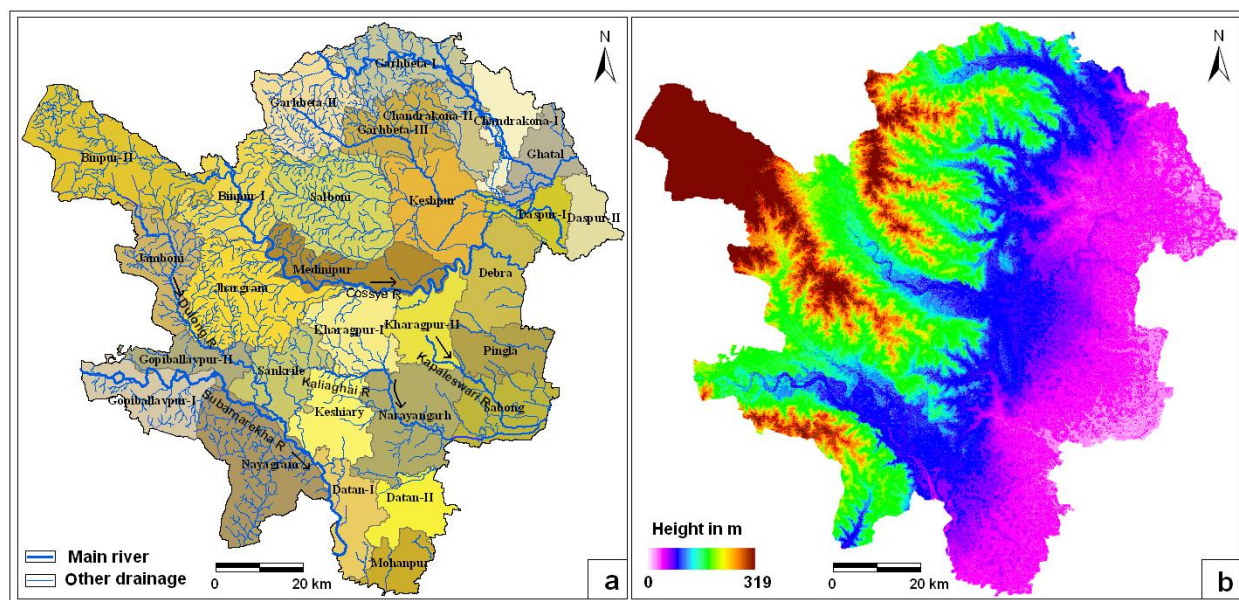

Fig. 2   Drainage map with block boundary (a) and relief map (b) of Paschim Medinipur, based on Satellite image and SRTM data

3.3 Creation of physical infrastructure data base in GIS

We have used secondary data from Census of West Bengal for infrastructure development assess in the block (S Sau, 2009) and mouza level. To supplement the secondary data, primary data have been collected by questionnaire and survey methods from gram panchayat, panchayat samity, municipality, zilla parishad, district planning office and government offices of the district. All the primary and secondary data have been analyzed by using simple statistical tools. We considered 20 variables for our study in the basis of multi-criteria decision making approach for each block of Paschim Medinipur. They are public service facility (bank, post office, co-operative societies and primary hat), transport facility (road length, railway access and bus root), public utility service (electricity and spot source water), medical facility (hospital, health centre, clinic and veterinary hospital), education facility (Sishu Siksha Kendras/SSK, Madhyamik Siksha Kendras/MSK, primary school, institution, college and university) and public welfare (library and family welfare centre).

Table 2

Block wise public service facility and transport facility data base for Paschim Medinipur

Block name	Mouza	Public survive facility (number)				Transport facility		
		Bank	Post office	Co-operative societies	Prima ry hat	Road density	Rail station distance	No. of Bus roots
Binpur-I	353	9	20	71	3	1.02	20	15
Binpur-II	470	10	32	79	3	0.78	25	7
Chandrakona-I	132	8	22	58	10	0.86	30	3
Chandrakona-II	131	4	20	39	4	1.17	18	9
Daspur-I	162	8	29	74	17	1.48	30	3
Daspur-II	87	9	30	59	20	1.48	25	3
Datan-I	199	7	25	50	38	1.02	2	5
Datan-II	128	6	22	34	0	1.40	12	2

Debra	477	13	46	143	18	1.50	0	10
Garhbeta-I	356	10	22	80	2	1.04	5	8
Garhbeta-II	334	8	20	84	5	0.71	19	8
Garhbeta-III	233	8	17	62	5	0.74	1	4
Ghatal	145	12	29	66	10	1.22	38	4
Gopiballavpur-I	216	7	26	142	10	1.08	45	3
Gopiballavpur-II	192	7	20	58	6	1.09	36	5
Jamboni	388	6	19	44	0	0.86	1	16
Jhargram	604	14	21	110	0	1.26	2	4
Keshiary	220	7	25	50	8	1.13	12	5
Keshpur	634	16	42	106	6	1.25	22	30
Kharagpur-I	268	28	18	134	2	0.87	0	22
Kharagpur-II	353	8	25	54	11	1.04	0	4
Medinipur	268	18	18	51	5	0.90	2	7
Mohanpur	103	4	18	35	0	1.35	22	4
Narayangarh	517	17	49	103	6	1.18	2	2
Nayagram	336	9	24	46	24	0.69	25	5
Pingla	182	7	30	93	18	1.31	11	24
Sabong	232	11	39	139	17	1.27	22	2
Salboni	528	13	23	66	2	0.78	0	3
Sankrile	287	8	17	39	7	0.96	45	5

One remarkable development during the economic reform period, 1994-95 to 2005-06 is that the number of commercials bank and gramin bank offices increased in three blocks, namely Jhargarm, Kharagpur I and Salboni. The lowest number of commercial bank offices (only 2) is located in Mohanpur block. On the other hand, number of co-operative societies for most of the blocks increased in this period. Debra block recorded highest number of co-operative societies (143). The lowest number of co-operative societies is located in Mohanpur block (35). The survey conducted by Paschim Medinipur Zilla Parishads reveals that total road length for the district was 1727.85 km as in August 2007 and track/ boulders road length amounted to 7101.30

km. Road length varied widely across blocks of the district, the highest being in Garbeta I followed by Jhargram and the lowest being in Daspur II. Number of originating / terminating bus routes also didn't increase for most of the blocks during the period. The number of mouzas electrified was highest in Debra followed by Keshpur and Salboni, the lowest being experienced by Datan II (Table 2).

Table 3

Block wise public utility service and medical facility data base for Paschim Medinipur

Block name	Public utility service (in number)		Medical facility (in number)			
	Electricity in mouza	Spot water source	Hospital	Health centre	Clinic	Vererinary
Binpur-I	247	29132	1	5	33	20
Binpur-II	192	29949	0	4	38	23
Chandrakona-I	122	23395	0	6	27	17
Chandrakona-II	120	20474	1	2	24	18
Daspur-I	156	36132	1	3	32	26
Daspur-II	86	41662	0	4	35	27
Datan-I	103	29014	0	3	28	27
Datan-II	52	26005	0	3	24	23
Debra	423	53945	1	4	48	44
Garhbeta-I	257	36150	1	3	39	38
Garhbeta-II	148	24910	0	3	28	31
Garhbeta-III	164	26600	1	3	26	26
Ghatal	136	37010	1	3	34	22
Gopiballavpur-I	58	18614	0	4	24	18
Gopiballavpur-II	106	18743	0	4	23	22
Jamboni	164	21537	0	3	26	28
Jhargram	292	31305	1	5	36	37
Keshiary	136	27748	0	4	28	26

Keshpur	352	52977	1	3	51	45
Kharagpur-I	97	23321	6	3	35	17
Kharagpur-II	194	33402	0	3	25	27
Medinipur	190	31556	6	3	28	32
Mohanpur	76	19516	0	3	19	14
Narayangarh	266	54081	1	4	46	47
Nayagram	93	26341	0	4	30	32
Pingla	157	35727	0	4	30	32
Sabong	173	46768	1	3	37	36
Salboni	304	32421	2	3	38	33
Sankrile	80	21355	0	3	23	29

Medical facilities, particularly sub-centers (clinics and dispensaries) increased appreciably during that period of time. Total number of beds also increased. However, the medical facilities varied widely across blocks of the district. Number of family welfare centers increased significantly across blocks of the district. Distribution of blocks by spot water sources shows that over 70 per cent of the families depend upon tube well. Infant mortality is low and there are blocks where it is nil. It varies across blocks; the highest being experienced by Sabang followed by garbeta-1block. Midnapore and Ghatal municipal areas also experienced significant infant death. Number of Veterinary Hospital remains constant and varies across blocks (Table 3).

Table 4

Block wise education facility and public welfare centre data base for Paschim Medinipur

Block name	Education facility centre (in number)					Public welfare	
	SSK	MSK	Primary school	Institu tion	College/ university	Public library	Welfare centre
Binpur-I	78	6	157	16	0	5	33
Binpur-II	110	8	170	21	1	5	36
Chandrakona-I	35	4	116	28	0	5	23
Chandrakona-II	30	3	110	21	1	4	23

Daspur-I	44	8	129	30	3	6	31
Daspur-II	24	9	162	36	0	5	34
Datan-I	71	9	108	19	1	4	27
Datan-II	48	7	92	19	0	4	23
Debra	145	9	206	39	1	8	44
Garhbeta-I	110	10	177	22	2	4	37
Garhbeta-II	78	10	166	18	0	6	28
Garhbeta-III	64	8	122	17	0	4	44
Ghatal	33	3	168	40	1	7	33
Gopiballavpur-I	62	5	131	12	1	5	21
Gopiballavpur-II	33	5	135	17	0	4	22
Jamboni	30	9	113	16	3	5	25
Jhargram	113	9	198	28	7	8	33
Keshiary	91	9	122	17	0	5	26
Keshpur	259	15	247	41	0	7	49
Kharagpur-I	99	7	97	36	5	6	30
Kharagpur-II	116	8	143	26	0	5	25
Medinipur	88	6	116	38	18	7	29
Mohanpur	29	5	81	14	0	4	18
Narayangarh	190	10	233	37	3	7	45
Nayagram	132	11	164	20	0	6	28
Pingla	48	7	144	29	2	6	29
Sabong	77	11	228	48	1	6	36
Salboni	148	10	166	25	1	5	35
Sankrile	79	10	151	14	0	5	22

As per the Paschim Medinipur District Primary School Council number of primary school is highest in Keshpur block followed by Narayangarh, both these blocks having the largest area and population. Number of Sishu Siksha Kendra was highest in Keshpur followed by Narayangarh. Keshpur registers the highest number of MSKs followed by Sabong and Nayagram. The data

from the District Inspector (Secondary Education) reveals that in Paschim Medinipur district during 2007-08 there were 728 secondary institutions. There were 32 Professional & Technical Schools, Colleges & Universities (Table 4) in the study area. All above twenty variables were used to build the block level GIS data base for Paschim Medinipur. We generated two thematic map using education and medical infrastructure facility using ArcGIS v10 software is shown in the Fig. 3a and 3b.
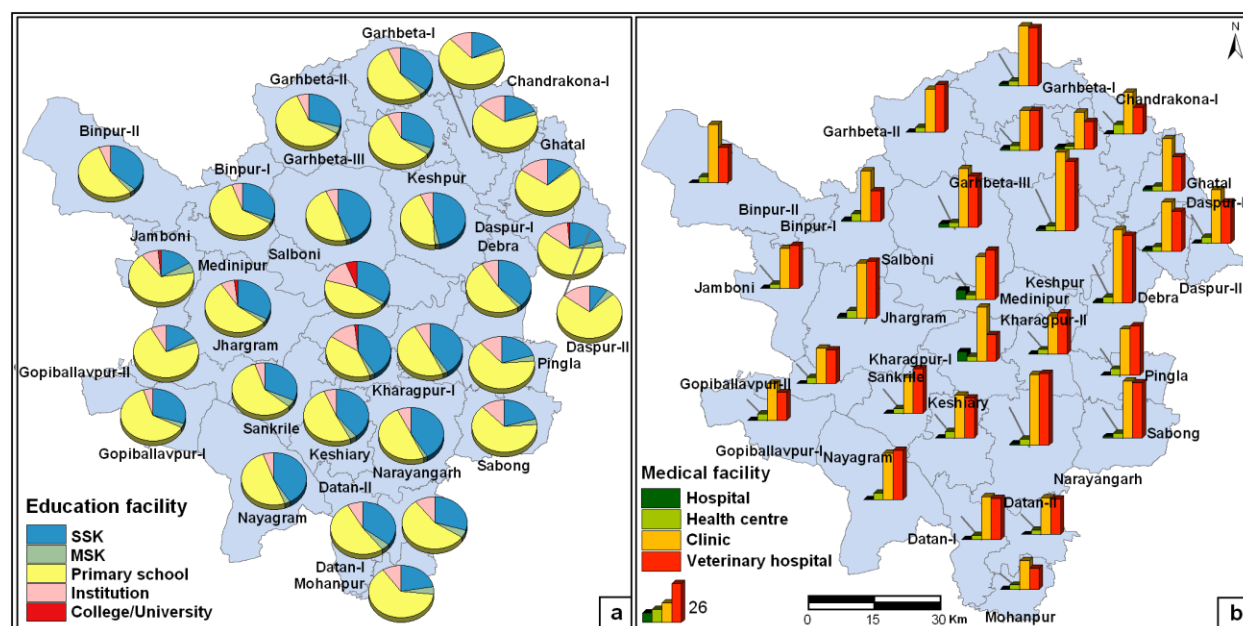

Fig. 3   Block wise Education (a) and medical (b) infrastructure facility map of Paschim Medinipur

3.3. Multi-criteria decision approach for block development

According to the degree of favorable infrastructure, simple statistical marking/weighting are used for all the blocks of Paschim Medinipur leading to multi-criteria decision support approach. All the details about marking/rating are given in table 5. ArcGIS-10 software is used to prepare public service facility, transport facility, public utility service, medical facility, education facility and public welfare layers. We devised the relevant index model (Fig. 4) in the model maker using the multi-criteria decision-making approach. All those twenty variables (Table 5) are used

as inputs in the index model. In the first step we produced the 'public service facility' using bank, post office, co-operative societies and primary hat layer, followed by 'transport facility' using road length, railway access and bus root layer; 'public utility service' using electricity and spot source water layer; 'medical facility' using hospital, health centre, clinic and veterinary hospital layer; 'education facility' using SSK, MSK, primary school, institution, college and university; and finally 'public welfare' composites for each block of Paschim Medinipur. We used quantitative analysis method using all variables according to the block area; population and number of mouza for marking each block. In the next step all infrastructure categories with calculated marks for each block are stored in the temporary output memory file. Finally we used them for the block development status analysis.

Table 5

Mark distribution to each variable to determine the block infrastructure development analysis

Infrastructure	Variables	Marks	Group marks
Public survive facility	Bank (Commercial and Gramin bank)	150	275
	Post office	50	
	Co-operative societies	50	
	Primary hat (market)	25	
Transport facility	Road density (km/sq km)	150	400
	Rail station distance	200	
	No. of Bus roots	50	
Public utility service	Electricity (no. of mouza electrified by Block)	100	150
	Spot water source (Tube well, well and others)	50	
Medical facility	Hospital	350	475
	Health centre	50	
	Clinic and dispensaries	50	
	Veterinary hospital	25	
Education facility centre	SSK (Sishu Siksha Kendras-child leaning centre)	25	

	MSK (Madhyamik Siksha Kendras)	25	650
	Primary school	50	
	Institution (Middle, High & Higher Secondary)	250	
	College/ University	300	
Public welfare	Public library	25	50
	Welfare centre (Family welfare centre)	25	
	Total	2000	2000

4.1 Result and discussion

We considered twenty variables for block wise infrastructure development assessment analysis. Bank, post office, co-operative societies and primary, road length, railway access, bus root, electricity, spot source water, hospital, health centre, clinic, veterinary hospital, SSK, MSK, primary school, institution, college/university, library and family welfare centre are used in the index model according to the infrastructure development assessment marking criteria. ArcGIS platform is used to prepare these marking maps after reclassifying all attributes for each variable. The "marking" and "sum" functions are used in the index model (Fig. 4) to produce the final output map for block wise infrastructure development assessment (Fig. 5). Table 6 shows all blocks of Paschim Medinipur with their total marks and rank according to the infrastructure development status, calculated in the multi-criteria decision approach using twenty variables by Erdas Imagine model maker (Fig. 4). According to the present infrastructure status Medinipur placed first rank (1st), followed by Kharagpur-I (2nd) and Daspur-I third rank (3rd). The rank of Nayagram block is the last (29th) due to the lack of infrastructure facility.
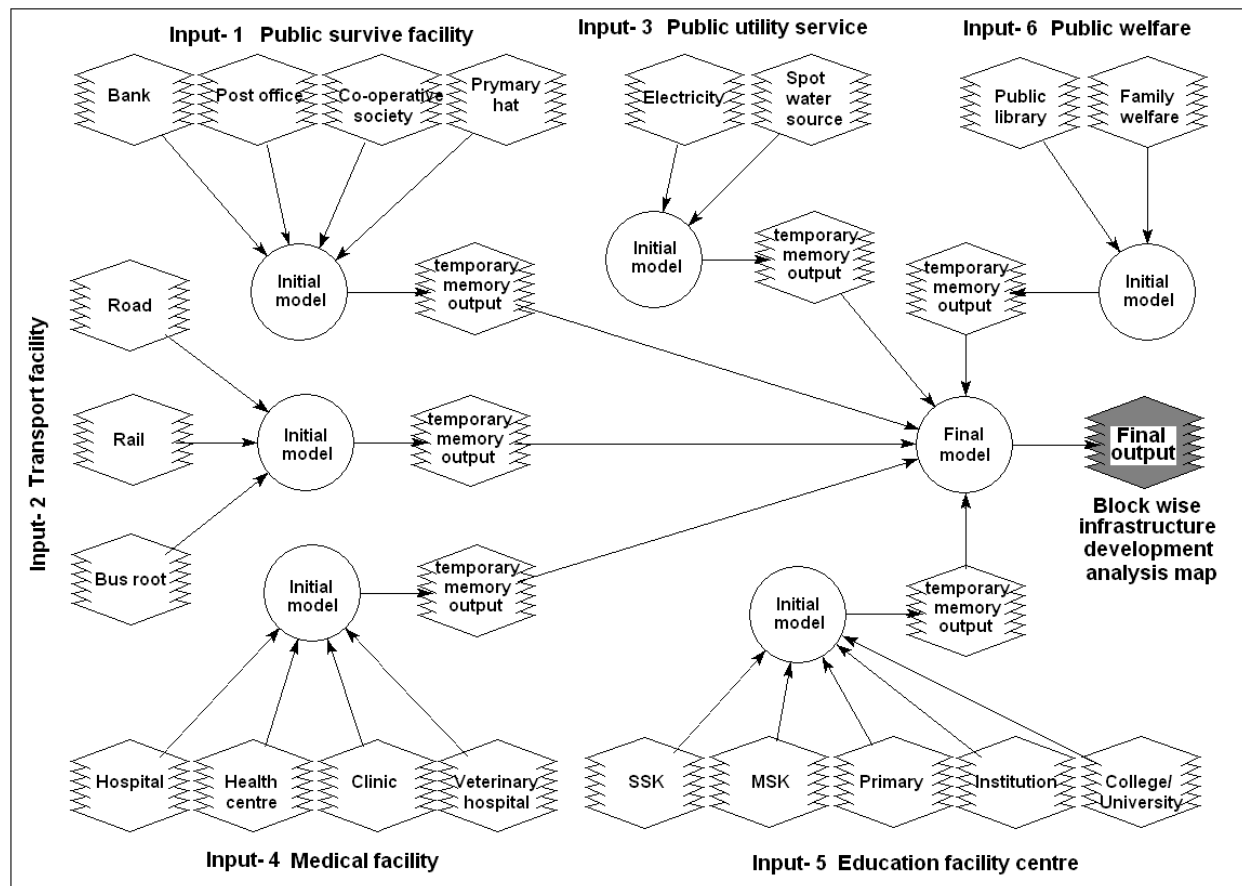
Fig. 4   Methodological flow chart for block wise infrastructure development analysis

Table 6

Block wise ranking system according to the twenty selected variables of infrastructure

Block name	Total marks	Rank	Block name	Total marks	Rank
Binpur-I	630	24	Jamboni	634	22
Binpur-II	424	28	Jhargram	721	17
Chandrakona-I	719	18	Keshiary	642	20
Chandrakona-II	927	7	Keshpur	730	16
Daspur-I	1224	3	Kharagpur-I	1252	2
Daspur-II	1105	4	Kharagpur-II	767	12
Datan-I	747	15	Medinipur	1392	1

Datan-II	756	14	Mohanpur	768	11
Debra	1008	5	Narayangarh	769	10
Garhbeta-I	758	13	Nayagram	411	29
Garhbeta-II	497	25	Pingla	968	6
Garhbeta-III	686	19	Sabong	923	9
Ghatal	924	8	Salboni	633	23
Gopiballavpur-I	490	26	Sankrile	455	27
Gopiballavpur-II	639	21			
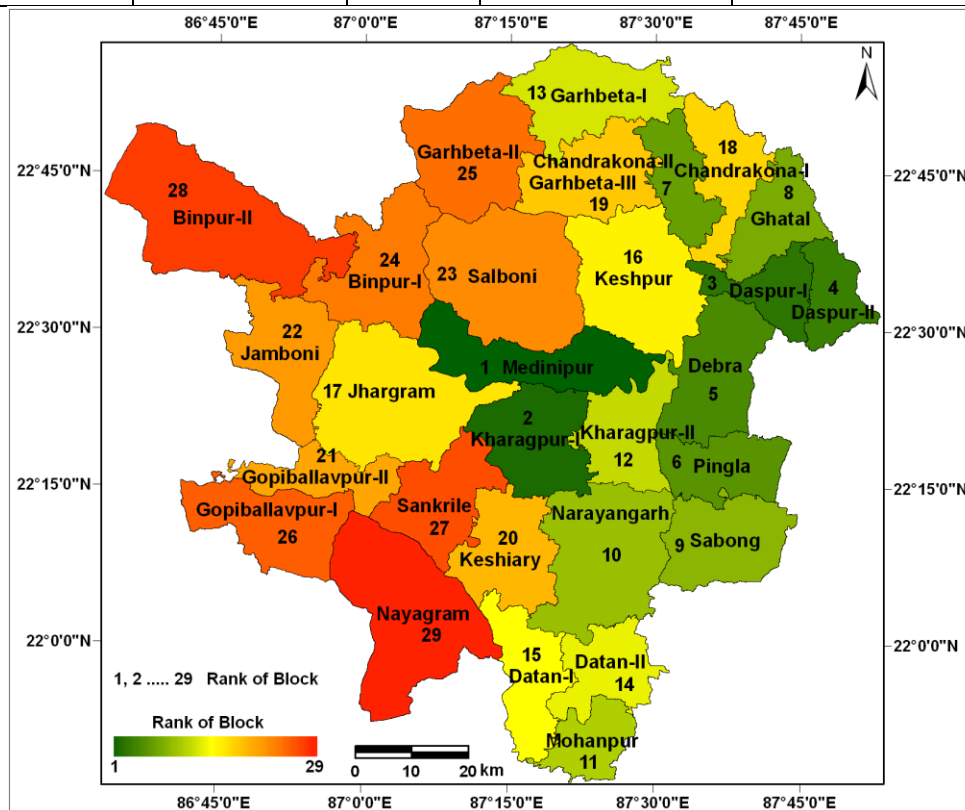
Fig. 5   Block wise backwardness and forwardness ranking map based on infrastructure facility

In relation to the infrastructure development assessment we try to represent the relation between mouza wise scheduled tribe (ST) population distribution (Fig. 6a) and total literacy (Fig. 6b). Western part of the study area, like Gopiballavpur-I, Binpur-II and Nayagram block having more percentage (> 60%) of ST population and the total literacy is very less (almost 20 %). The infrastructure development is not sufficient and that's why these blocks are backward (fig. 5).
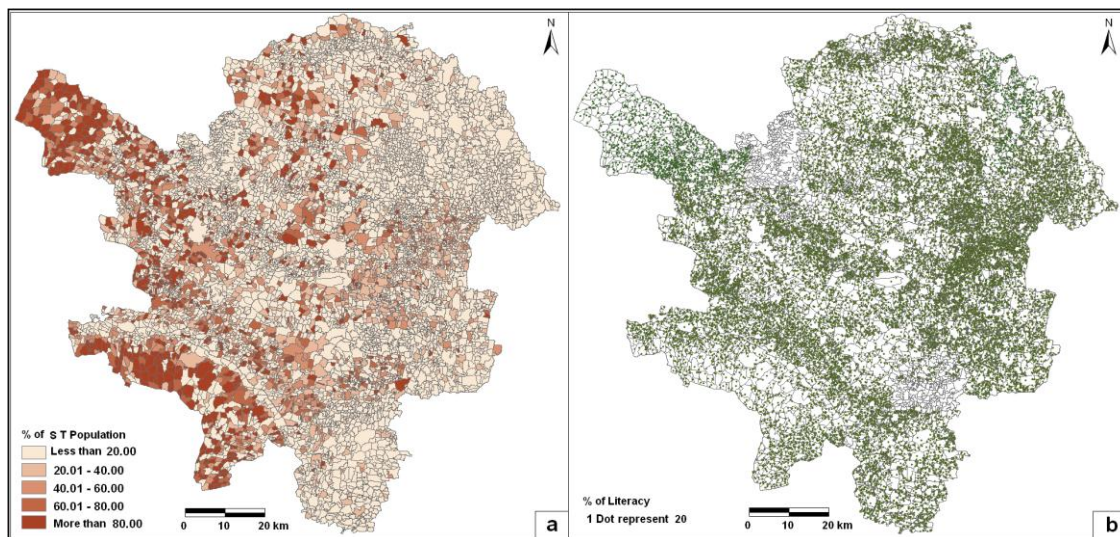
Fig. 6   Mouza wise percentage of ST population (a) and total literacy (b) map, based on census data

Finally we have drawn the comparison between mouza wise percent of irrigated land (Fig. 7) and percent of cultivated land (Fig. 7b) of the study area. In the north and east parts of Paschim Medinipur district are well facilitate by the irrigation system, so farmer uses the land rapidly for crop production. Lack of irrigation system in other area caused only single crop practiced in the rainy season.
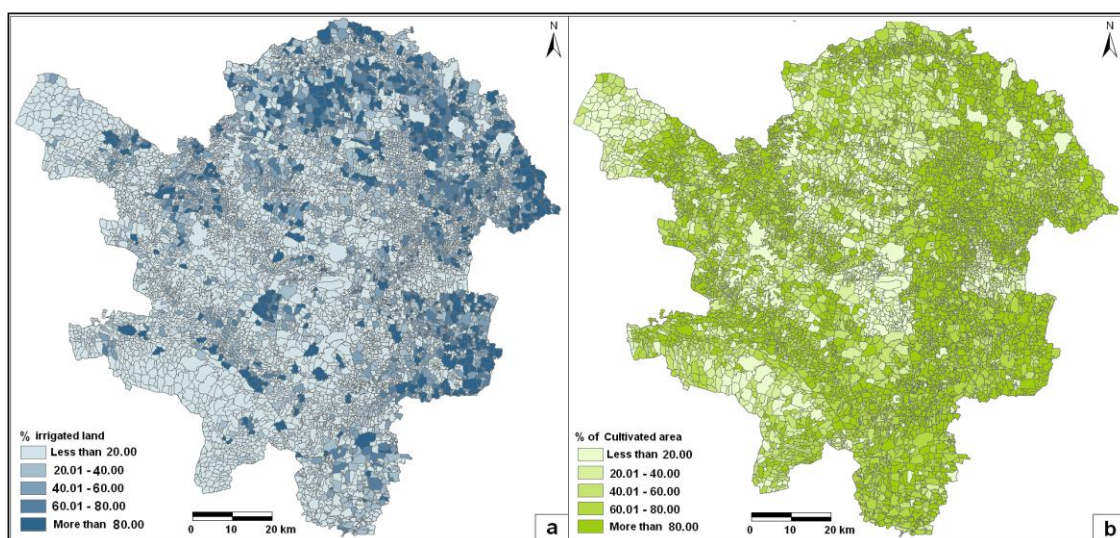

Fig. 7   Mouza wise percentage of irrigated land (a) and cultivated land (b) map, based on census data

5.1 Conclusions

Infrastructure development analysis is carried out for entire Paschim Medinipur district, West Bengal. Spatial multi-criteria decision-making approach is used with twenty physical infrastructure variables, as input in the model, like public service, transport, public utility service, medical, education and public welfare facilities. Medinipur, Kharagpur-I and Daspur-II are the top three ranked blocks of the Paschim Medinipur, have all kind of infrastructure facility. In the future study we can attempt Ggram Panchayat (GP) level or village level analysis and mapping on similar theme for Paschim Medinipur district with further refined parameters.

Acknowledgements

References

[1] Coltelli M, Fornaro G, Franceschetti G, Lanari R, Migiaccio M, Moreira J R, Papathanassaou K P, Puglisi G, Riccio D and Schwabisch M, *SIR-C/X-SAR multifrequency multipass interferometry: A new tool for geological interpretation*, Journal of Geophysical Research, vol. 101, pp. 127-148, 1996.

[2] Dowding S, Kuuskivi T and LI X, *Void fill of SRTM elevation data – principles, processes and performance, In: images to decisions: remote sensing foundations for GIS applications*, ASPRS, Fall Conference, September 12-16, Kansas City, MO, USA, 2004.

[3] Fisher P F and Tate N J, *Causes and consequences of error in digital elevation models*, Progress in Physical Geography, vol. 30, pp. 467-489, 2006.

[4] Fulmer J, *What in the world is infrastructure?,* PEI Infrastructure Investor (July/August), pp. 30–32, 2009.

[5] Gamache M, *Free and low cost datasets for international mountain cartography*, Documentation for the Alpine Mapping Guild, vol. 42, 2004a.

[6] Infrastructure, http://education.yahoo.com/reference/dictionary/entry/infrastructure (accessed October 27, 2011)

[7] S Sau, *Database for Planning and Development of West Bengal*, Vol. II, 2009.

[8] Steven M S, *Economics: Principles in action,* Upper Saddle River, New Jersey 07458: Pearson Prentice Hall, pp. 474, 2003.