© June 2025 | IJIRT | Volume 12 Issue 1 | ISSN: 2349-6002

Changing Water Resources Study using GIS and Spatial Model-A Case Study of Katwa Subdivision,District Purba Bardhaman,West Bengal, India

Tapas Kumar Ghosh[1], Prof Parbati Nandi[2]
[1]*Research Scholar, Seacom Skills University*
[2]*Guide, Seacom Skills University*

***Abstract*—Ground water that exists beneath the earth surface in soil and rock formation. It is a vital resource for drinking, irrigation and industry. Primarily from rainfall that infiltarates the ground. Found in aqufiers, which are porous rock formation that can hold and transmit groundwater. A significance source of fresh water for various uses, including drinking water agriculture and industry. Groundwater is part of the water cycle, where it can seep into streems, lakes, and oceans or be drawn up by plant. Katwa subdivision in west bengals Purba Bardhaman district relies heavily on ground water, particularly for irrigation. The area is part of the Ganga-Brahmaputra alluvial plain, making it ideal for groundwater extraction.**

***Index Terms*—ORIGIN, STORAGE, WATER CYCLE, IMPORTANCE, CONTAMINATION.**

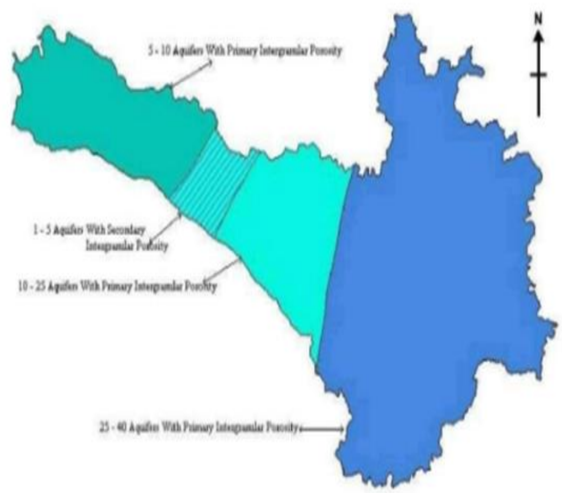
Water Resources & Management

There are many tanks, wells, canals, swamps and bils are found all over the district. Within the Damodar Valley region, there are around 17000 tanks. The Durgapur barrage and Mithon dam have formed two large reservoirs at the south-western and western periphery of the district. In this district there are two major source of irrigation –
1. Damodar Valley Command Area
2. Mayurakshi Command Area

Out of the 33 blocks, 20 blocks are irrigated by DVC area and 2 blocks, KetugramI and II are by Mayurakshi Command area. Other sources of irrigation are Deep Tube well, shallow tube well, River lift Irrigation etc.
Ground Water

As per information received from the Water Resource Investigation Department it is understood that the surface water taping is only 11 percent. The blocks of surface water taping include Barabani, Faridpur-Durgapur, Kanksa, Ausgram I & II, Salanpur Raniganj, Jamuria, Andal and Pandebeswar. The problem of rainwater harvesting is prominent in this district – non-availability of land is one of the major constraints in harvesting rain water. In the lateritic zone community land can be utilized for rainwater harvesting structure.

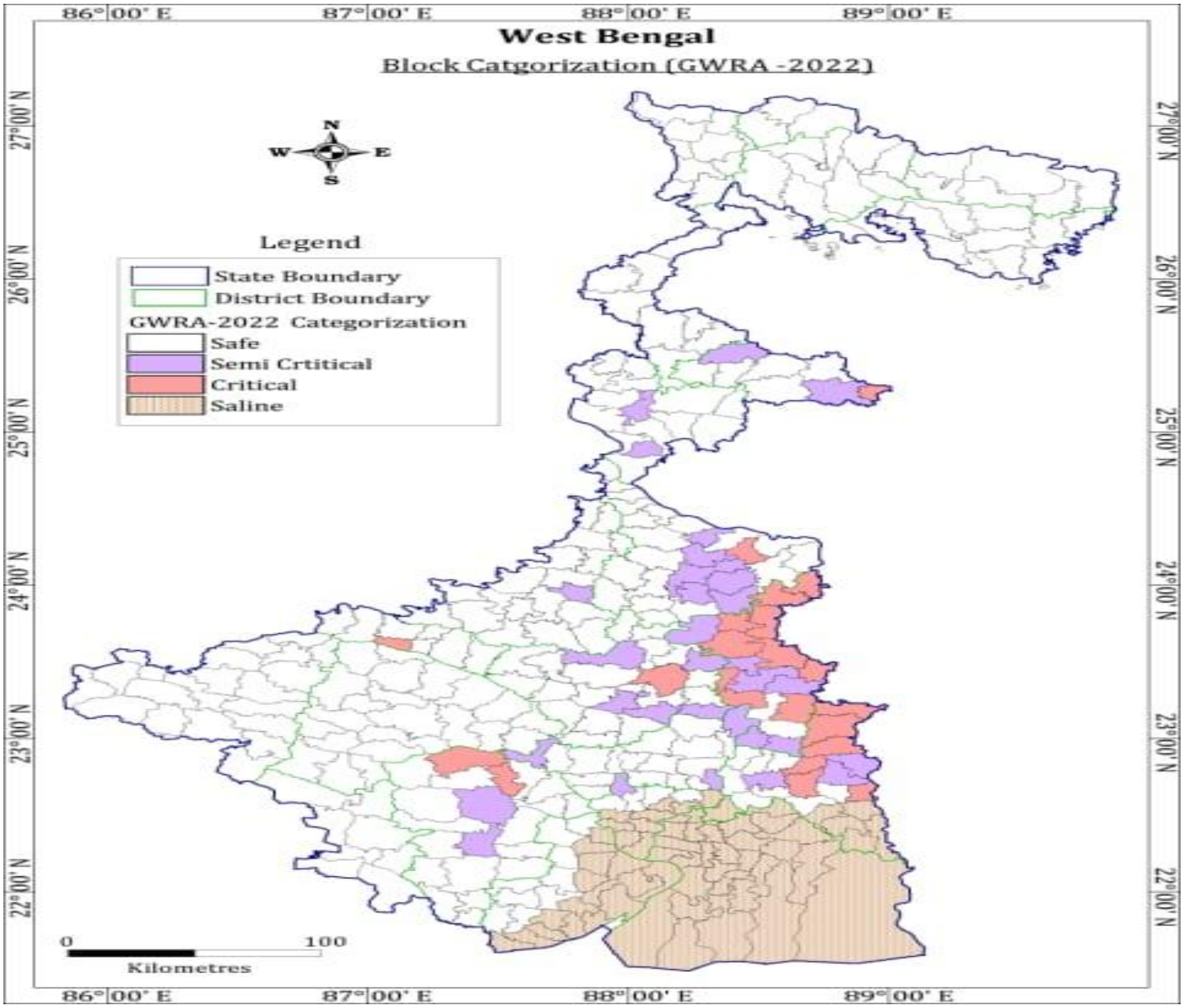
The subdivision of Asansoland Durgapur is unfit for lifting groundwater. Bhatar, Monteswar, Ketugram I, Memari II, Purbasthali – II, and Mangalkot blocks are critical for lifting ground water under DTW. The problem of Arsenic infestation exists in Kalna – I and Burdwan Sadar, is almost saturated by irrigation through canal and groundwater.



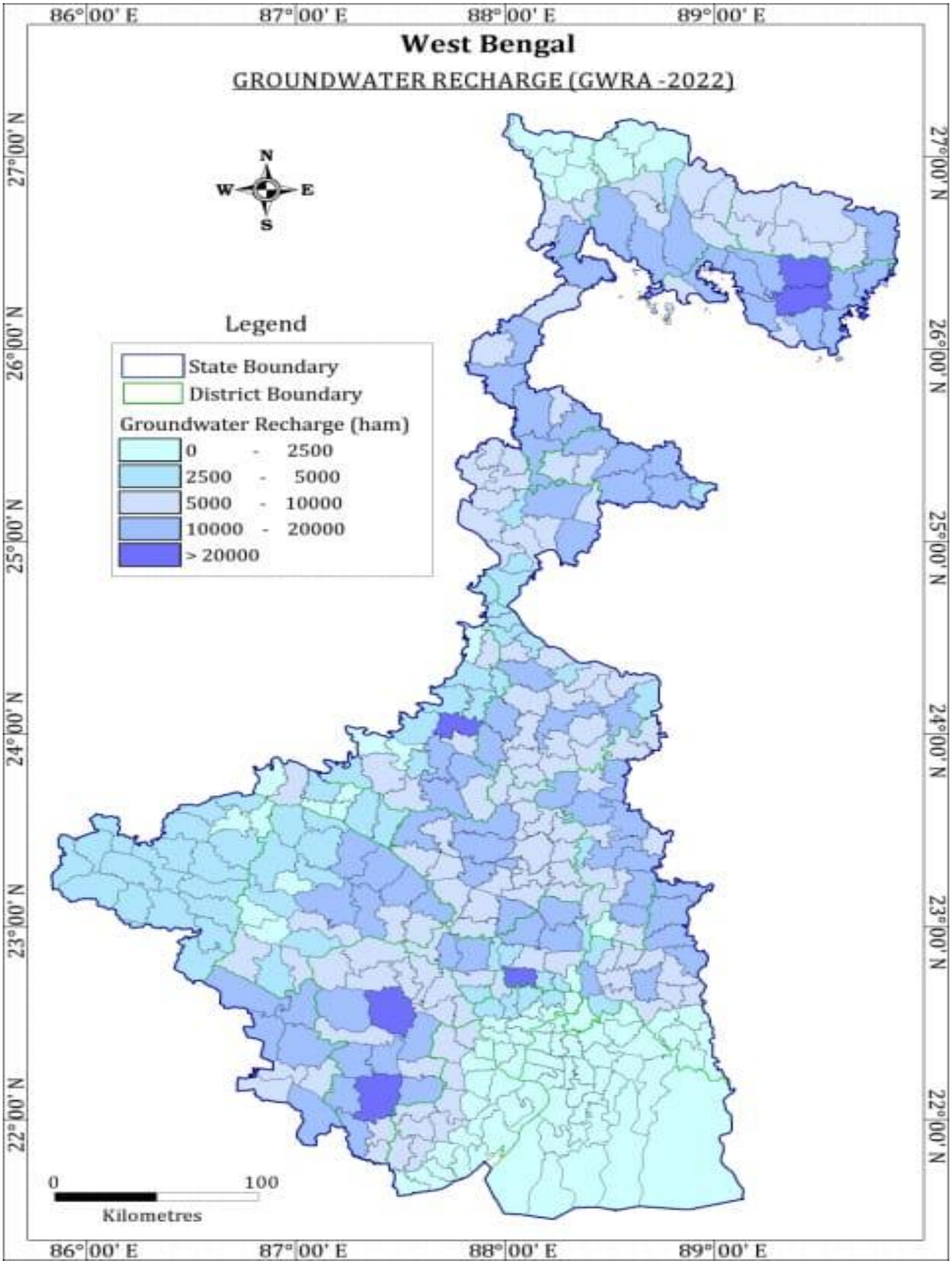
Aquifer map of the district showing Categorization of Assessment Units

ASSESSMENT UNIT WISE RESOURCE POSITION

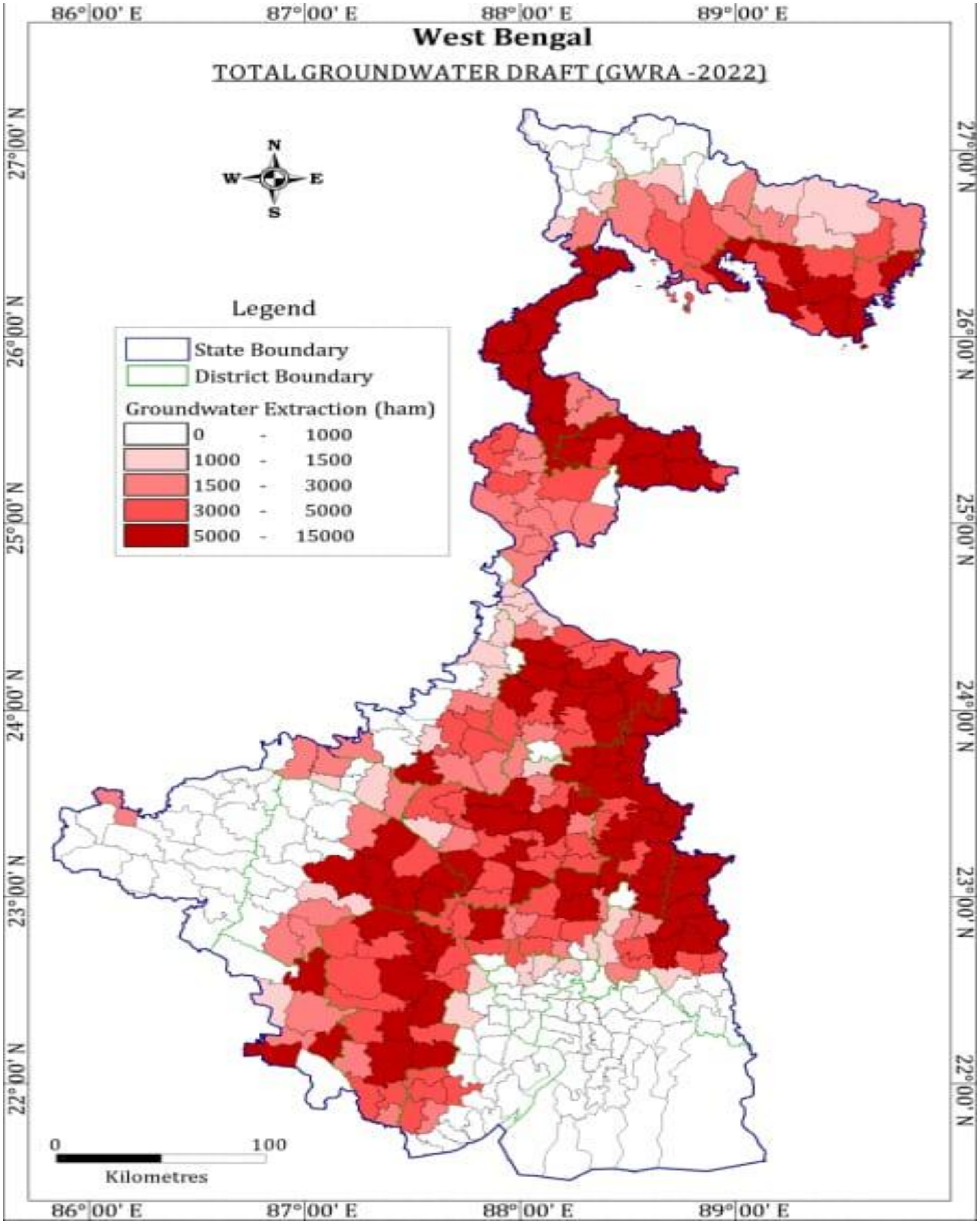
District	Assessment Unit Name	Total Area of Assessment Unit (Ha)	Recharge Worthy Area(Ha)	Recharge from Rainfall - Monsoon Season	Recharge from Other Sources - Monsoon Season	Recharge from Rainfall - Non Monsoon Season	Recharge from Other Sources - Non Monsoon Season	Total Annual Ground Water (Ham) Recharge	Total Natural Discharges (Ham)	Annual Extractable Ground Water Resource (Ham)	Ground Water Extraction for Irrigation Use (Ham)	Ground Water Extraction for Industrial Use (Ham)	Ground Water Extraction for Domestic Use (Ham)	Total Extraction (Ham)	Annual GW Allocation for for Domestic Use ason 2025 (Ham)	Net Ground WaterAvailability for future use (Ham)
Purba Barddhaman	Katwa-I	17747	17747	3595.47	264.78	827.49	486.24	5173.98	258.70	4915.28	1778.80	0.00	588.73	2367.52	621.26	2515.23
Purba Barddhaman	Katwa-Ii	17356	17356	3928.10	285.49	809.26	595.58	5618.43	280.92	5337.51	2658.00	0.00	344.18	3002.19	363.37	2316.13
Purba Barddhaman	Ketugram-I	19398	19398	3293.42	375.89	904.47	658.37	5232.15	523.22	4708.93	1470.00	0.00	415.64	1885.64	438.44	2800.49
Purba Barddhaman	Ketugram-Ii	16003	16003	3841.70	374.85	746.18	576.40	5539.13	276.96	5262.17	889.00	0.00	290.51	1179.51	303.18	4069.99
Purba Barddhaman	Mangolkote	36544	36544	7755.63	645.77	1703.94	948.05	11053.39	1105.34	9948.05	6377.00	0.00	655.76	7032.76	689.14	2881.91



Map showing Categorization of Assessment Units



MAP SHOWING SPATIAL VERIATION IN GROUND WATER RECHARGE



MAP SHOWING SPATIAL VARIATION OF GROUND WATER EXTRACTION

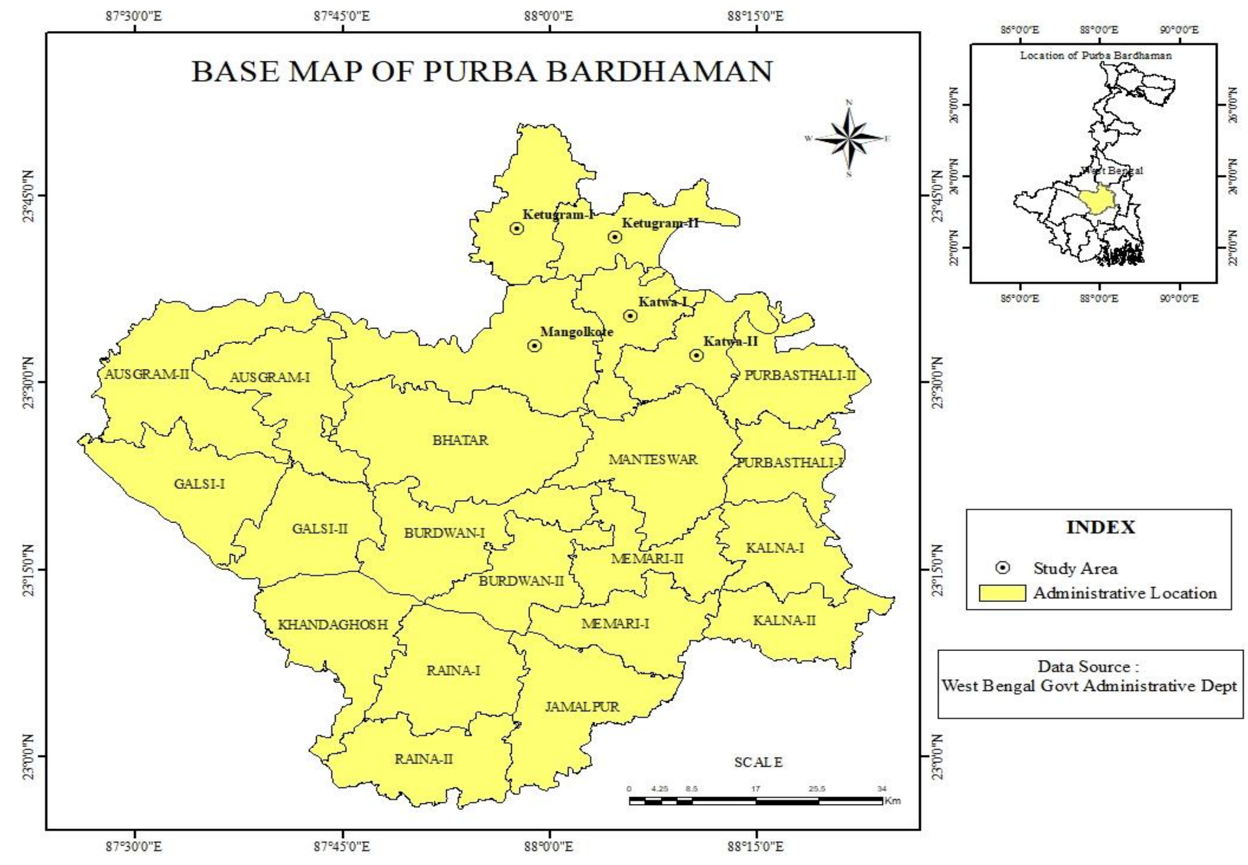
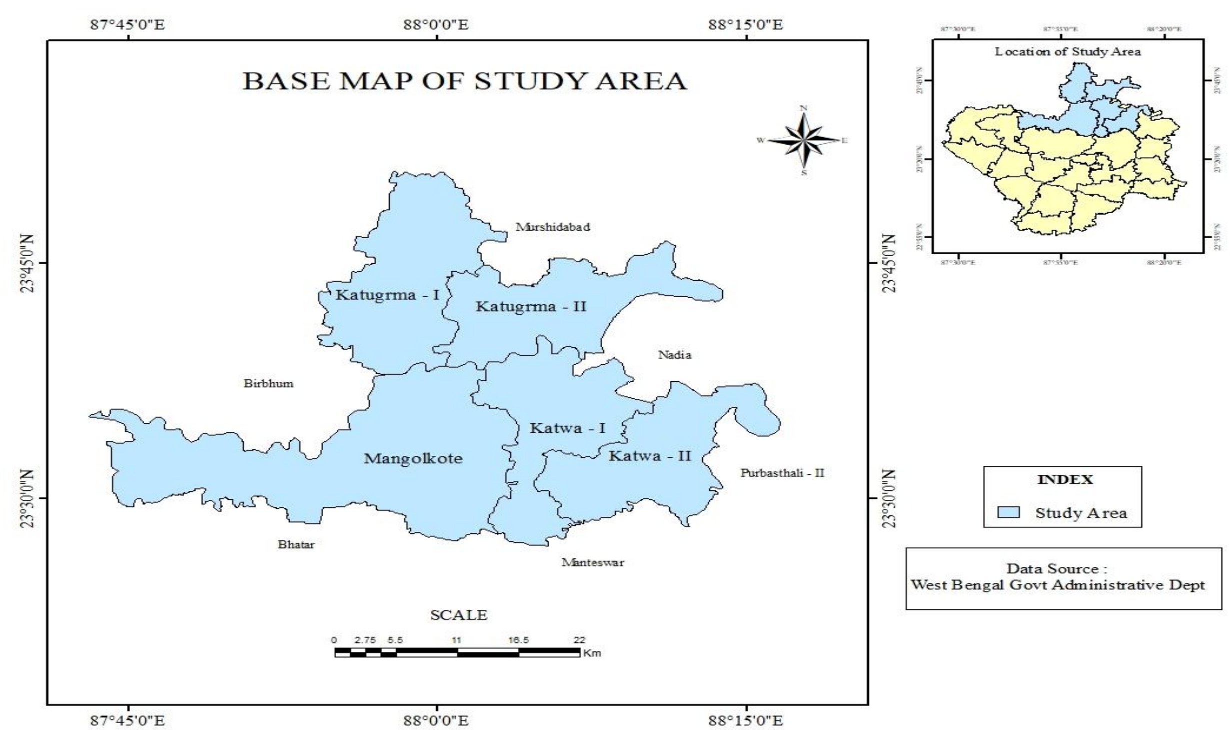

BASE MAP OF PURBA BARDHAMAN
87°30'0"E
87°45'0"E
88°0'0"E
88°15'0"E
23°45'0"N
23°30'0"N
23°15'0"N
23°0'0"N
Ketugram-I
Ketugram-II
Katwa-I
Katwa-II
Mangolkote
AUSGRAM-II
AUSGRAM-I
PURBASTHALI-II
BHATAR
MANTESWAR
PURBASTHALI-I
GALSI-I
GALSI-II
BURDWAN-I
KALNA-I
MEMARI-II
BURDWAN-II
KHANDAGHOSH
MEMARI-I
KALNA-II
RAINA-I
JAMALPUR
RAINA-II
SCALE
0 4.25 8.5 17 25.5 34
Km
Location of Purba Bardhaman
86°0'0"E
88°0'0"E
90°0'0"E
26°0'0"N
24°0'0"N
22°0'0"N
West Bengal
INDEX
Study Area
Administrative Location
Data Source :
West Bengal Govt Administrative Dept

Table 1

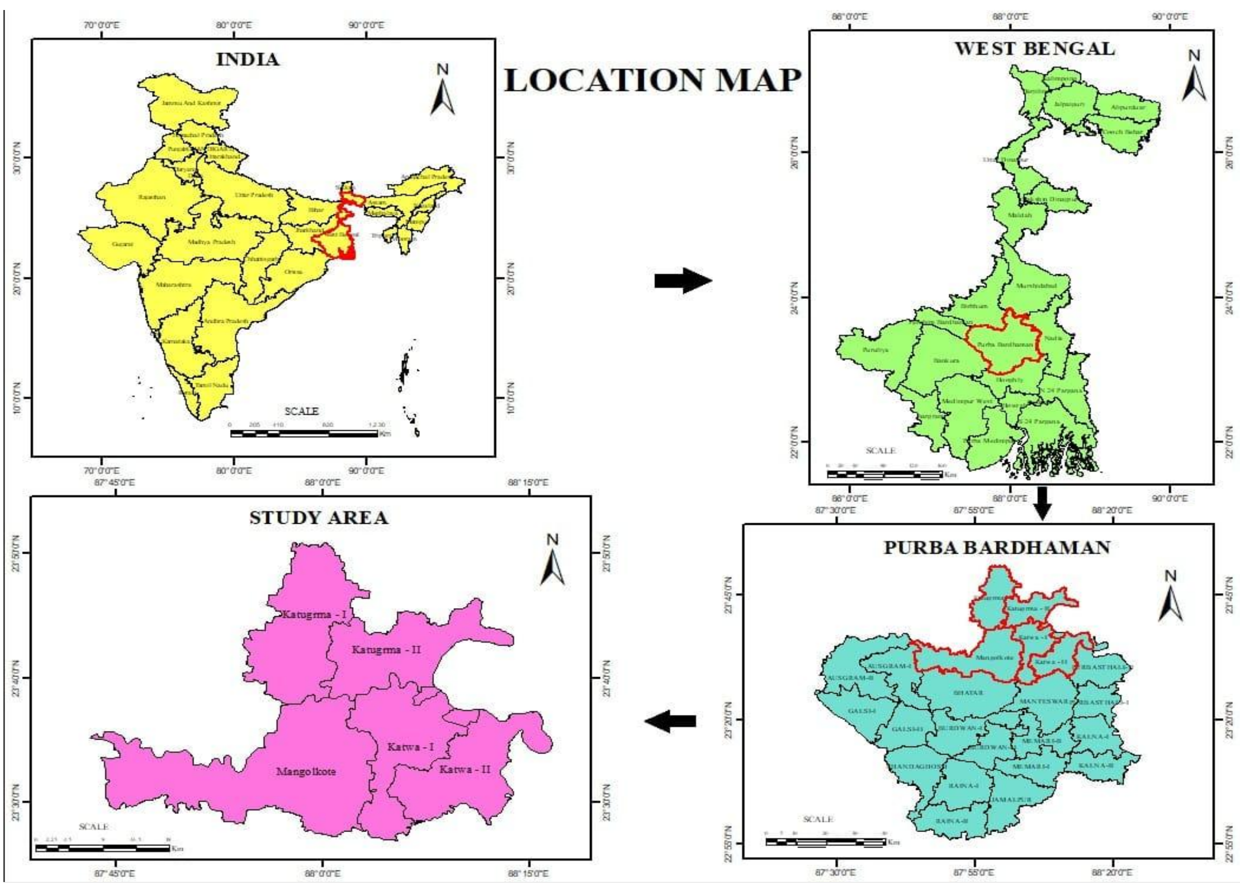

BASE MAP OF STUDY AREA
87°45'0"E
88°0'0"E
88°15'0"E
23°45'0"N
23°30'0"N
Murshidabad
Katugrma - I
Katugrma - II
Nadia
Birbhum
Katwa - I
Mangolkote
Katwa - II
Purbasthali - II
Bhatar
Manteswar
SCALE
0 2.75 5.5 11 16.5 22
Km
Location of Study Area
INDEX
Study Area
Data Source :
West Bengal Govt Administrative Dept

STUDY AREA: Katwa subdivision is an administrative subdivision of the Purba Bardhaman district in the state of West Bengal, India. This subdivision is located 23.65N and 88.13E. The Katwa subdivision extends from the Kanksa-Ketugram plain to the Bhagirathi basin. The ajay river flows through the subdivision and joins the Bhagirathi River Purba Bardhaman district is divided into the five administrative subdivision such as (1) Bardhaman sadar north, (2) Bardhaman sadar south (3) Katwa (4) Kalna (5) Purba Bardhaman district.

Katwa subdivision has 3 police station,5 community development blocks,5 panchayat samitis, 46 gram,388 mouzas,373 inhabited village, 2 munnicipalities and 1 census town. The municipalities are Katwa municipalities and Dainhat municipalities, the census town is Panuhat. The subdivision has its headquarters at Katwa. community development blocks in Katwa subdivision are-

SL NO	C D BLOCK	HEADQUARTERS	AREA(Km2)
1	MONGALKOTE	NATUNHAT	365.44
2	KETUGRAM-1	KANDRA	193.98
3	KETUGRAM-2	GANGATIKURI	160.03
4	KATWA-1	KATWA	168.94
5	KATWA-2	DAINHAT	163.20

Purba Bardhaman district was formed on 7 april 2017 after bifurcation of the erstwhile Bardhaman district and its headquarters is Bardhaman. Some historians link the name of the district to the 24th and last Jain tirthankara, Mahavira Vardhamana,who came to preach in the area. It was a forward frontier zone in the progress of Aryanisation by the people in the upper gangetic valley. Purba means east. Bardhaman district was bifurcated into two districts, Purba Bardhaman and Paschim Bardhaman.



I. INTRODUCTION

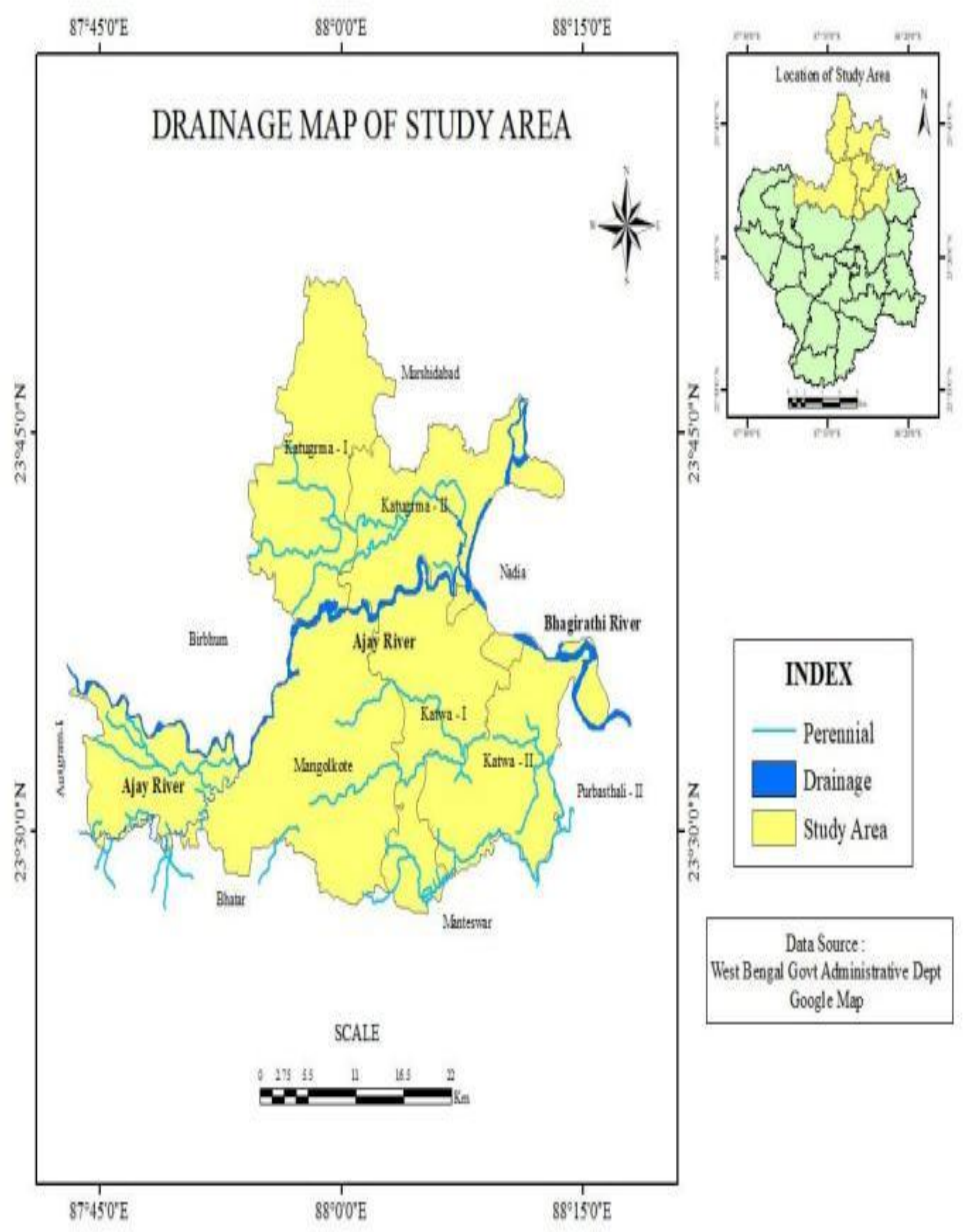
Land use and land cover are critical ingredients of human livelihood from the perspective of socio-economic conditions, climatic changes and sustainability, and changes in the patterns of land use and land cover are emerging as critical components of social,economic and climatic changes across the globe. Different types of human activities over the past three hundred years have resulted in vast changes in natural cover -a net loss of approximately 6 million km²of forest, A net gain of about 12 million km²of crop land, and a net loss of approximately 1.6 million km²in wetlands (Turner et al,1993). These changes are likely to alter structure, function,and complexity of local ecology with critical implications for maintenance of biodiversity at genetic,species,and landscape scales (NCR,1993; Vitousek,1994). Changes are likely to strain our capacity to meet basic natural resource needs of many of the indigenous groups of people. The 1992 United Nations Conference on Environment and Development (UNCED)stated that land use/land cover changes are important elements of the global environment change processes (Dickinson,1995; Hall et al.,1995). Thus, trend in land use changes merits closer analysis in recent times.

Changes in land use /land cover are often studied using various spatial models. Models are powerful tools to understand and analyse the important link between socio-economic processes associated with land development, agricultural activities, natural resource management and the function of eco-systems.Summarising a large number of case studies, we find that land use change is driven by a combination of the following fundamental high level causes:resource scarcity leading to an increase in the pressure of production on resources,changing opportunities created by markets,outside policy intervention,loss of adaptive capacity and increased vulnerability and changes in social organization in resource access and in attitudes.A current review highlights as many as 19 land use change models for their spatial,temporal,and human decision- making characteristics for comparing and reviewing land use change models(Agarwal et al,2001).

The models that have been used by researchers

Spatial Markov model has been used to model spatial changes in a variety of spheres. Changes in social situations,economic standards, natural resource availability,and even weather conditions have been explored and predicted using Markov Random Function (MRF)and Markov Random Chains (MRC). Markov analysis of vegetation types tends to focus on a small area of less than a few hectares or on a single small plot. When a few hundred hectares of land is involved, data sampling is usually applied to limit the workload to scattered plots or transects (Baker,1989). On the other hand,land use studies using Markov chain models tend to focus on a much larger spatial scale, and involve both urban and non-urban covers (Drewett,1969; Bourne,1971; Bell,1974; Bell and Hinojosa,1977; Robinson,1978; Jahan,1986; Muller and Middleton,1994). All of these studies use the first-order Markov chain models. The order of the Markov chains has only been formally tested in a few studies(Bell,1974;Robinson,1978) .Stationarity has usually been assumed,except in a few instances where it has been tested (Bourne,1971;Bell,1974; Bell and Hinojosa,1977).Brown et al.(2000)recently presented an approach to estimating transition probabilities between two binary images in a study of land use and land cover relationship in the Upper Midwest,USA.This approach,according to Huber (2001),needs to be improved and generalised in order to estimate properly Markov transitions from a pair of images

Markov modelling of land use and land cover changes have not been substantially complemented by satellite imagery and digital image processing technique.Previous studies mostly utilise data sampled from field surveys,existing maps or aerial photography(Drewett,1969;Boume,1971;Bell,1974; Bell and Hinojosa,1977;Robinson,1978;Jahan,1986; Muller and Middleton,1994).Data uncertainty in these studies remains relatively high,because only a certain amount of sites were sampled.The use of satellite imagery would create an opportunity for improved analysis.Moreover,the Markov



models have mostly been employed for studies around a city or a slightly arger area,with a regional concentration in North America.The application of stochastic models needs to be done in order to develop an operational procedure that integrates the techniques of satellite remote sensing,GIS,and Markov modelling for monitoring and modelling land use and land cover changes.In this paper,we try to use data extracted from GIS based maps/images in an MRC to obtain present transition probabilities and predict future changes in land use for a selected region in India.This serves both as an example of using frontier methodology for socio-technological research,and also as a cautionary note drawing attention to depleting water availability in the study area.

Methodology:Markov chain

Markov chain models have several assumptions (Parzen,1962; Haan,1977; Wang,1986; Stewart,1994). One basic assumption is to regard land use and land cover change (or other variables for that matter)as a stochastic process,and different categories are the states of a chain.A chain is defined as a stochastic process having the property that the value of the process at time t,X,depends only on its value at time t-l,X,,and not on the sequence of values Xrz, X_3;…...Xo that the process had passed through in arriving at X.y.It can be expressed as:

$P\{X=aj|X_0\text{-}aq,X_1=a,\ldots X=a \quad\}=P\{X_1=aj|X_1=a\}$(1)

Moreover,it is convenient to regard the change process as one which is discrete in time (t=0,l, 2…).

The $P\{X_1=a;X_{11}=a;\}$,known as the one-step transitional probability,gives the probability that the process makes the transition from state a;to state a; in one time period.When n steps are needed to implement this transition,the P {X=ajX_=a;}is then called the n step transition probability,P"j.If the P"is independent of times and dependent only upon states a,,a,,and n,then the Markov chain is said to be homogeneous.The treatment of Markov chains in this study will be limited to first order homogeneous Markov chains.

In this event:

$P\{X=a\}X_{11}=a;\}=P_1$ where Pi can be estimated from observed data by tabulating the number of times the observed data went from state i to j,ny,and by summing the

number of times that state a;occurred,n;.Then

$P_1=ni/n_1$

As the Markov chain advances in time,the probability of being in state j after a sufficiently large number of steps becomes independent of the initial state of the chain.When this situation occurs,the chain is said to have reached a steady state.Thenthe limit probability,Py,is used to determine the value of P";;:

$\lim,P^4\gamma=P\}$ where,

P;=P,P^%,j=1,2…m(state)

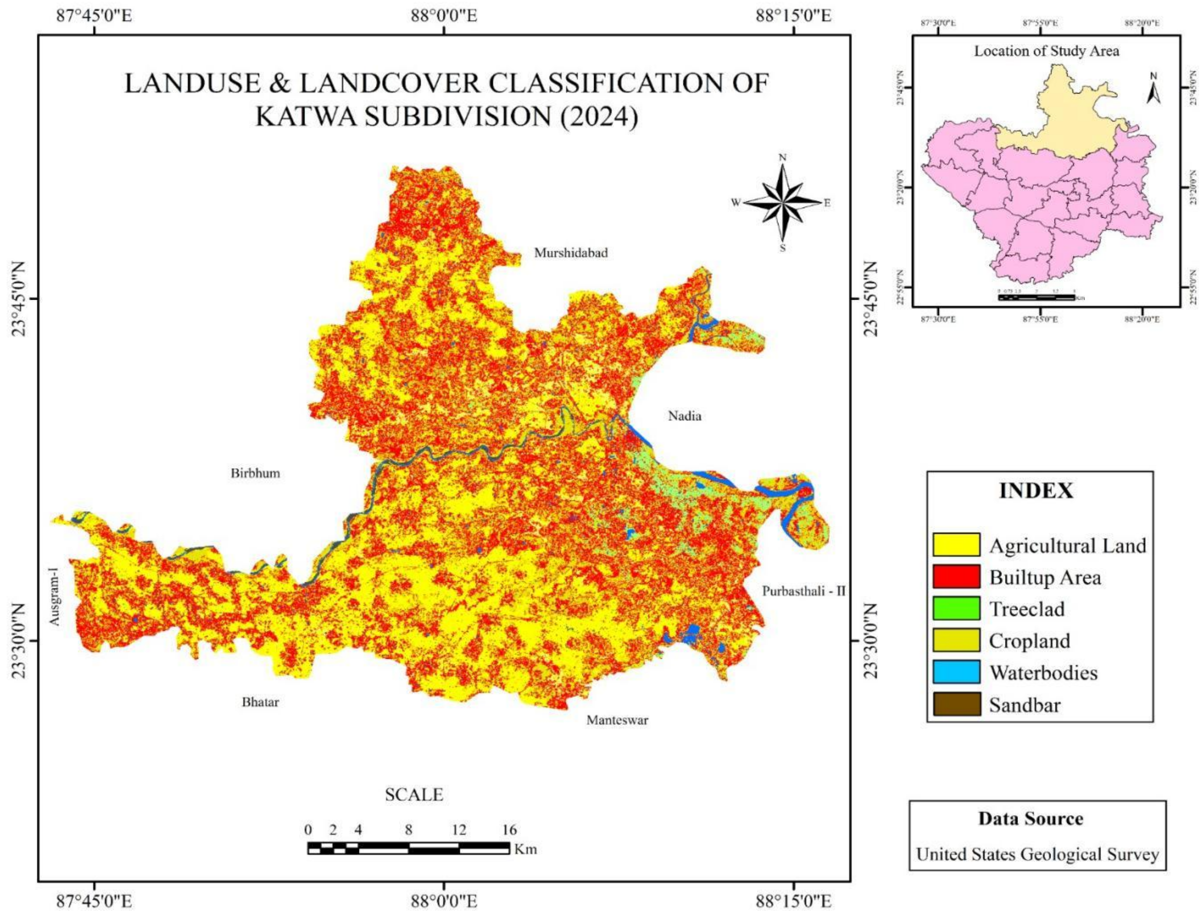
P=1P>0

As land use and cover change reflects the dynamics and interplay of economic,social,and biophysical factors over time,it would be implausible to expect stationarity in land use/cover data.However,for our practical purpose there is no harm in first assuming that a steady state will be reached.This would give us the steady state numbers of each of the i types. We can then relax the steady state assumption and indicate the likely movements in the TP matrix (hastening or slowing down of transition rates) and therefore arrive at a range or interval estimation of the numbers rather than having point estimation.

A specific case has been chosen to study and spatially-model the depletion of surface water-bodies in Katwa Subdivision Blocks of the district Purba Bardhaman West Bengal, India.

Agricultural activities in the police station have increased in terms of area too. In 1971 Katwa subdivision had 73%of its total area as agricultural land. The agricultural land use area coverage increased to 80%of its total geographical area in 2001.The growth of the agricultural land is thus quite substantial in the police station.

The area not available for cultivation reduced to 16%in 2001 mostly because of an effort to bring more lands from the area not available for cultivation to agricultural use.Though expansion of agricultural land use was prominent,irrigation coverage did not increase at the same rate,as mainly the location of the police station is such that canal irrigation is limited.Most of the irrigation therefore is being made by lifing from the surface water bodies,and as a result dependence on the ground water has increased.



At the same time,the ground water resource is declining at an alarming rate.It is observed that while average depth of the water table was about 09 metres in 2001, in 2014, the average depth became 14 metres. The January water depth was 7.90 metres in 1990, and as low as 15.0 metres in 2005.

In April the maximum depth the pre-monsoon water table was 11.16 metres in the year 1990.It also shows declining trend,but with fluctuations.The pre-monsoon water depth was about 20 metres in 1996 indicating maximum withdrawal of the water from the ground water reserve in the preceding season. After that the depth was restored to about 15-16 metres due to good monsoon in 2002-05. But still the declining trend is obvious.

In August,the post monsoon month,we can expect the ground water to come closer to the surface.But the water table of the Katwa Subdivision blocks does not show any such pattern and lies between the January and April water table.While in 1990, the depth of the post-monsoon water table was 9.62 metres,it stands at 14 metres in 2005.

The water of the Ajay River and its tributaries (in monsoon season)is also being used for irrigation.But most of the water flows to Ajoy River and then to Bhagirathi,while the villages remain dry and have shown steady decline in the water table depth.According to State Water Investigation Directorate (SWID),Burdwan,Govt.of West Bengal, Bhatar block is categorized as 'over exploited'in ground water as it has been using up 100%of its ground water reserves.

Thus,it is clear that ground water withdrawal is occurring at a much faster rate compared to recharge.Depletion of water table by 50%in 15 years is alarmingly high.At this rate of depletion the region will enter the list of Dark Block'in a span of next 15 years.LULC changes and depleting surface water bodies ith the above situation in the background,we tried to examine the LULC changes in villages in Katwa subdivision.ithin the Katwa Subdivision The village is also facing the same problem of decreasing the water table and at the same time the number of surface water bodies. Surface water bodies of 1926 overlaid by 100 Sq.Meter Grid.

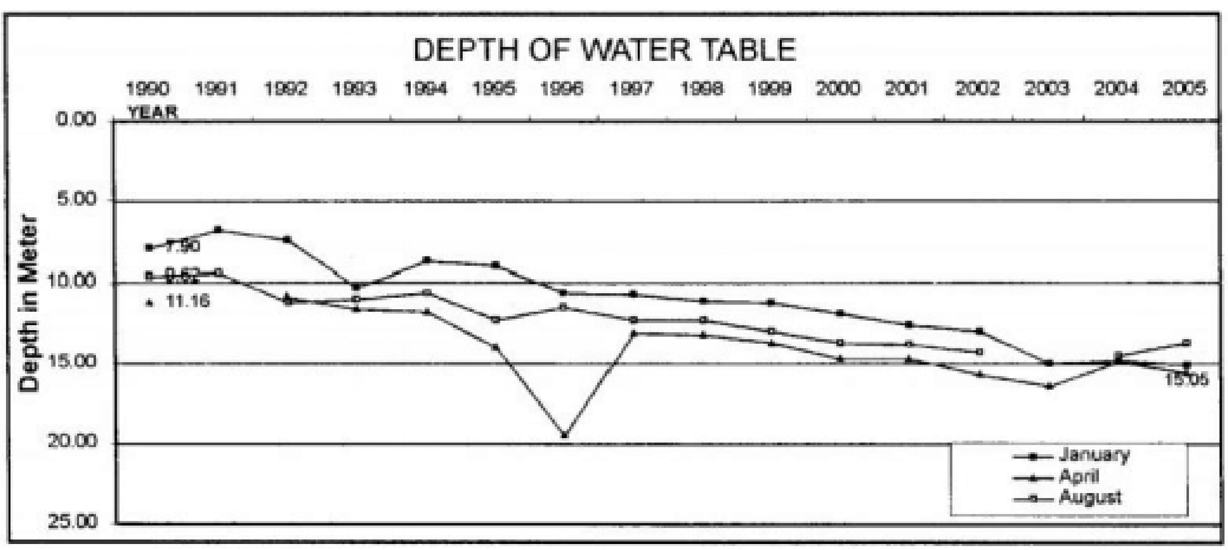
Depth of ground water of Katwa Subdivision

It has been observed that the surface water bodies of the region are declining in number and most of them become almost dry during the dry season.		Water Table	Data(Depth in meter)		
	January	April	August	Fluctuation	Average Depth
2005	7.90	11.16	9.62	1.54	9.56
2006	6.82	N.A.	9.44	N.A.	5.42
2007	7.35	10.89	11.20	-0.31	9.81
2008	10.32	11.59	11.02	0.57	10.98
2009	8.69	11.84	10.55	1.29	10.36
2010	8.95	13.95	12.25	1.70	11.72

Declining trend of water table of Katwa Subdivision

2011	10.55	19.52	11.50	8.02	13.86
2012	10.70	13.10	12.29	0.81	12.03
2013	11.06	13.16	12.31	0.85	12.18
2014	11.20	13.71	13.01	0.70	12.64
2015	11.86	14.66	13.66	1.00	13.39
2016	12.56	14.66	13.83	0.83	13.68
2017	12.96	15.66	14.26	1.40	14.29
2018	15.04	16.40	N.A.	N.A.	10.48
2019	14.80	14.91	14.46	0.45	14.72
2020	15.05	15.61	13.70	1.91	14.79

Source:SWID (Burdwan)



Source:SWID-WB.

Cross-tabulation of cells in Katwa Subdivision

Distribution of Cells	Type-I	1974 Land Type-II Land	Distribution of cells	Type-I	2020 Land Type-II Land
1926 Type-I Land	90	79	1974 Type-I Land	89	22
Type-II Land	21	565	Type-II Land	1	633

Source:Author's calculation

For the next period,i.e.that between 1974-2000, this one- step transitional probability,is given by 89/111=0.801. Similarly,'P'robability that a given cell was NOT a

Water body in 1926 but was converted to a Water body in 1974 is given by:

P_3=P{Xt=a|X-I=a}=21/565=0.037

The same probability for the 1974-2000 period is given by 1/633=0.001.

Thus, the net depletion rate was 47%during the 50 years between 1926-1974, and in the next 25 years it was 20%. Since depletion took place at a compound rate,such results clearly indicate a much faster rate of degradation of surface water bodies in

the second period,i.e.in recent times.The probabilities of depletion per year are increasing over time.At this rate,the probability of depletion shall be 0.50 for next 25 years and hence the number of water bodies would deplete to 46 in the next 25 years, i.e.by 50%-a case of serious concern no doubt. This is depicted in Table 6.

There is thus clear indication of unsustainable changes in LULC in the PS,where extension of agricultural activities is leading to depletion of ground water table and degradation /drying up / conversion of surface water bodies as well.

Table 6 Depletion of water bodies in Bhatar PS-spatial modelling using Markov Chain

Year	Type-1 Land (Waterbodies	Type-II Land (Agri.&Sett
1926	169	586
1974	111	644
2000	90	665
2025*	46	709
Steady State*	37	718

Source:Author's Calculation

Note: *indicates Estimation by Markov Modelling

The region is thus facing a serious threat in its surface and ground water situation.The threat comes from the changes in land use and land cover, especially due to substantial extension of agricultural activities which is expanding at a very fast rate. Increasing population also demands more lands for settlement and industrial uses.

In addition,the cultivators need more and more water for sustaining the extended agricultural activities and prefer to use the available surface water as its use is less costly.The surface water bodies

i.e.the ponds etc.are used for such intensive irrigation purposes.As a result the surface water bodies depletes before the onset of summer.The cultivators use those dried up ponds or surface water bodies for agricultural purposes also.There is thus a serious trend to convert the surface water bodies into the agricultural land.In addition,rampant use of ground water for irrigation is also leading to alarming drop in water table.Thus LULC change in the region is associated with depletion of water bodies and lowering of ground water table at an alarming rate.It is estimated using MRC,that in next 25 years,the number of surface water bodies will deplete by 50%in the agriculturally active Bhatar PS at the current rates of depletion.

Increasing economic activities and changing LULC at the cost of surface water bodies and depleting ground water table may prove costly in the long run.As water table goes down and ponds dry up more and more effort and expenditure will be required for irrigation.Consequently,poor and marginal farmers will find it extremely difficult to carry on farming for most of the non-monsoon seasons.This will create both socio-economic unrest as well as depletion in agricultural production. The sustainability of the present form of extensive cultivation and intensive irrigation is therefore questionable

Perhaps shifting to less water needy crops, prevention of LULC conversion,and water

harvesting would provide some solace to the situation.

REFERENCES

[1] Agarwal, C. Green,Glen M., Grove, J., Morgan.Evans. Tom P.and Schweik Charles, M.2001, A review and assessment of land use change models:dynamics of space,time,and human choice.Gen.Tech.Rep.NE- 297.Newton Square.PA:U.S.Department of Agriculture,Forest Service,North-eastern Research Station:61

[2] Baker.W,1989, "A Review of Models of Landscape Change",Landscape Ecology 2:111-113

[3] Bcll,E.J.and R.C. Hinojosa,1977, "Markov Analysis of Land Use Change:Continuous Time and Stationary Processes",Socio-Economic Planning Sciences 1l: 13-17

[4] Bell, E.J,1974, "Markov Analysis of Land Use Change -An Application of Stochastic Processes to Remotely Sensed Data",Socio-Economic Planning Sciences 8(6): 311-316

[5] Berry M.W., B.C.Hazen,R.L.Macintyre,and O.F. Richard,1996, LUCAS: A System for Modelling Land Use Change,IEEE Computational Science and Engineering 3:24

[6] Boume, L.S,1971, "Physical Adjustment Processes and

[7] Land Use Succession",Economic Geography 47,1-15.

[8] Brown D.G,Brown,P.Goovacrts.A.Burnicki and M.Y. Li,2000, "Stochastic Simulation of Land-Cover Change Using Geostatistics and Generalized Additive

[9] Models",Photogrammetric Engineering &Remote Sensing,68:105I-1061

[10] Chomitz,K.M.and Gray, D.A.1996, Roads,land use, and deforestation:a spatial model applied to Belize. World Bank Economic Review 10(3):487-512

[11] Dickinson, R., 1995.Land process in climate models. Remote sensing of Environment 51.27-38

[12] Drewett, J.,1969, "A Stochastic Model of the Land Conversion Process",Regional Studies 3:269-280

[13] Fitz, H.C., E.B. DeBellevue, R. Costanza.,R.Boumans.

[14] T.Maxwell,L.Wainger,and F.H. Sklar.1996. "Development of a General Ecosystem Model (GEM)

[15] for a range of scales and ecosystems", Ecologieal Modeling 88: 263-297

[16] Giruh, PT, Marsh, S.E, and hami, R., 1995, *A Dупатіс Spatial Model ofShifting Cultivation in the Highlands of Guinea, West Africa', Ecologica[Modelline 79: 179- 197

[17] Наэп. C. T., 1977. Satisiical Methods in Hydrotogy.Ames, lowa, The lowa State lIniversity Press.

[18] HaH, E C, Townesend, 1.R. and Engman, E.T., 1995, Status of Remote Sensing algorilhms lor esimation of Land surface state parameters, Remote sensing o/ Fnwironment 51: 138-156.

[19] Hardie, 1. W. and, P.1. Parks, 1997, "Land Use with Heterogeneous l.and Qualiy: An Applicaton of an Area Base Model', 3. Agric. Econ. 79: 299-310.

[20] НиЬег M, 2001, *Esrimatng Markov Transiions", Jurnalof Environmenial Managemen 61: 381—385

[21] Janan, 8. 1986, The Determination of Stability and Simiiarity of Markovian Land Use Change Processes: A Theoretical and Empirical Analysis, Socio-Econ Planning Science 20: 243-251

[22] Kates, R.W., BL. Turner ll, and W.C. Clark, 1990, "Thc Crea! Transformation", In the Earth as Transformed Ьу Нитап Action. eds. B.L. Turner, II, W.C. Clark. R. W. Kates, 1.E. Richards, 1.T. Mathews, ana W.B. Meyer, Cambridge, Cambridge Universiy Press: 1-17

[23] Landis. 1.D-and M. 2hane. 1998, *The Second Oeneration of the California Urban Futures Model: Part 2: Specification and Culibration Results ofthe Land Use Change Submodel", Environment and Planninв . B B- Planning & Design 25(5): 657-666

[24] Mertens, B. and E.F. 1ambin, 1997, "Spatial Modelling of Deforestation in Southern Cameroon", Applied Сеодгарну, 17(2): 143 - 162

[25] Muler, M.R. and 1. Middletn, 1994, *A Магкоу МоделI о[Land Use Change Dynamics in the Niagara Region,

[26] Ontario, Canada", Landscape Ecology, 9(2):151-157

[27] MCR (Natonal Research Counci1), 1993, The Role Of

[28] Terrestrial Ecosystems in Global Change. National

[29] Асадету Press, Washington, DC

[30] Parzеп, E., (1962) - Siochastic Processes. San Francisco, Holden-Day

[31] Robinson. V. B. 1978. *lnformation Theory and Sequences of Land Use: An Application', The Projessional Geographer 30: 174-179
[32] Stewart,). Q., 1947, *Empirical Mathematical Rules Concerning the Distribution of Equilibrium of Population",Geographical Review 37: 461-548
[33] Swallow, S.K., P Talukdar, and D.N. Wear, 1997, "Spatial and Temporal Specialzation in Forest Ecosystem
[34] Managcmcnt under Solc Owncrship", American Journal of Agricultural Economics, 79: 311-326
[35] Turner, B.L. 2001, Land-Use and Land-Cover Change: Advanccs in 1.5 Decades of Sustained lnternational Research. GAlA-Ecoiogical Perspectives in Science, Humanities. and Economics 10 (4): 269-272
[36] Veldkamp, A. and L.O. Fresco, 1996a, *CIIIE: A Сопсерша Modelto Stdy the Conversion of land Use and is Effects", Ecological Modeling, 85:253-270
[37] Veldkamp, A. and l..O. Fresco, 1996b. "CIUE-A: Aп lntegrated Muli-Scale Model to Simulate land Use Cnanee Scenaros in Cosia Rica', Ecoloeical Modeline. 9I2-3): 253-270
[38] Vitousek, P.M. H.A. Моопсу. 1. Lubchenco,). M. Melilo.1997, Human Dominationof Earth's Ecosystems, Science 277: 494-499
[39] Voinov, A., R. Costanza, L.A. Wainger, R. Boumans,. E. Villa, т. Maxwell, and H. Voinov, 1999, "Patuxent Landscape Model: lnlegrated Ecological Economie
[40] Modeling o[a Waershed", Environmemal Modellne d Softare, 14
[41] Wanв. X., 1986. Multvariate Statistical Analysis of Geological Data, Betine. China, Science Press, (Iп Chinese).
[42] Wear, D.N. R. Apt, and R. Mangold, 1998, *People, Space, Time: Faciors That Will Govern Forest Sustainability", Transactions of the 63rd North American Wildltfc and Natural Resources Conference. Washington, D.C., WildIife Management lnstitute: 348- 361
[43] Wear, D.N., R. Liи, 1.M. Forcman. and R.M. Shelfield, 1999, "The Efects of Population Orowth on Timber Management and lnvcntorics in Virginia", Forest Ecology and Мапауетепі 118: 107-115
[44] Wood, E.C., 1. E. Lewis, G.C Таррап, апа R.W.Lietow, 1997, *The Development of a l.and Cover Change Model for Southern Sencgal', Presented at land Use Modelng WorАзпор, EROS Data Centre. Sioux Fals, S.Daka