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Research Article

IMPACT OF LULC CHANGES ON SURFACE WATER RESOURCE: A SPATIAL MODELLING APPROACH

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ABSTRACT
This paper focuses on analysis of LULC change and its impact on surface water condition with Spatial Murkov Model of Eruar grampanchayat, Burdwan District. Over 80 % population of the area is engaged in agricultural pursuits. The study area has experienced over 20% increase of agricultural land during last 40 years. Number of ponds of the area has decreased with increasing agricultural land during last few decades. The depletion rate of surface water bodies during last 36 years is very significant. A clear indication of unsustainable changes in LULC in the area is seen. The extension of agricultural activities and settlement area is leading to depletion of surface water resource. The result of the analysis indicates that the annual rate of depletion of water body is showing positive trend over time. Measures can be taken against these are tank rejuvenation may be an important way in which water can be conserved for both surface and groundwater irrigation. The situation also invites alternative cropping pattern and alternative cropping methods for more sustainability.

Key Words**:** *MRC, MRF, Standing Water Bodies, Rabi Cultivation, Steady State Condition, Alternative Cropping*

INTRODUCTION
Water resources are completely affected by global changes principally land use land cover (LULC) changes (Demuth and Radojevic, 2011). In earlier days, water has been measured as a limitless resource. But, mankind are dependent on a mere fraction of one percent of freshwater that existed in lakes, rivers, and groundwater aquifers as that water is the only freshwater which is readily available (Kataoka, 2002).The water requirements of agriculture sector are large than water requirements for other sector. It is estimated that rain based agricultural field could be down 50 % by 2020, owing to increase of irrigated land (IPCC, 2007). Thus, it is clear that the agriculture has, absolutely, been very successful at consuming the major portion of the world's utilizable water resources and it is largely accountable for water depletion of the world. Markov Chain Analysis is a expedient tool for modelling land use land cover (LULC) change when changes and processes in the landscape are complicated to explain (Opeyemi, 2006; Houet and Hubert Moy, 2006). Biswas (2009) has stated that the 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). Markovian chain analysis is used to illustrate LULC change from one stage to another (Opeyemi, 2008). This model is beneficial. Long-term predictions can be made basis of rates of past change and the spatial changes of complex systems can be simulated with more precision and realism (Wijanarto, 2006; Opeyemi 2006; Huishi, 2012). This chain can then be represented as a transition matrix (Gohlke, 2006). LULC change transition probability in Markov analysis indicates the probability of construction a transition from one land use type to another within two separate periods (Rimal, 2011; Alexakis *et al.*, 2013). With other, a crucial assumption is to regard LULC change as a stochastic process, and different categories are the states of a chain (Weng, 2001). A chain is defined as a stochastic process having the property that the value of the process at time t, X_t, depends only on its value at time t-1, X_{t-1}, and not on the sequence of values X_{t-2}, X_{t-3};…….. X_0 that the process had passed through in incoming at X_{t-1}.
Thus it can be formulated as:

$P\{X_t=aj|X_0=a_0, X_1=a_1,\ldots X_{t-1}=a_i\}$
$= P\{X_t = aj|X_{t-1} = a_i\}$ (1.1)

Furthermore, it is suitable to watch the transform process as one which is distinct in time (t= 0, 1, 2….). The $P\{X_t =aj|X_{t-1}=a_i\}$, recognized as the one-step transitional probability, gives the probability that the process makes the transition from state ai to state aj in one time period. While n steps are necessary to apply this transition, the $P\{X_t=a_j|X_{t-1}=a_i\}$ is then called the n step transition probability, P^n_{ij}. Whether P^n_{ij} is independent of times and dependent on states a_i, a_j, and n, at that moment the Markov chain is called homogeneous. The dealing of Markov chains will be restricted to first order homogeneous Markov chains. Here: $P\{X_t=aj|X_{t-1}=a_i\}= P_{ij}$ (1.2)

When P_{ij} can be projected from pragmatic data by tabulating the number of periods the experimental data go from state i to j, n_{ij}, and by summing the number of periods that state a_i occurred, n_i. After that

$P_{ij}=n_{ij}/n_i$ (1.3)

As the Markov chain progresses in time, the probability of being in state j after a adequately vast number of steps becomes independent of the primary state of the chain. When this condition occurs, the chain is said to have reached a steady state. Then the limit probability, P_j, is used to decide the value of P^n_{ij}:

$\lim_n P^{(n)}_{ij}=P_j$ (1.4)

Where:

$P_j=P_i\ P^{(n)}_{ij}$ j=1, 2,…...,m (state)

Pi=1 Pj>0

As LULC change reflects the dynamics and interaction of economic, social, and biophysical factors over time, it would be improbable to expect stationarity in LULC data (Weng, 2001). However, for our practical intention there is no harm in first presumptuous that a steady state condition will be reached, because the time extent is not too large. 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 and therefore appear at a range or interval estimation of the numbers more willingly than having point estimation (Biswas, 2007; Biswas, 2009).In the present study Markov model is used as a descriptive and inquiring tool to understand and compute the land use changes that happened over a human dominated region.

Location of the Study Area

Eruar Gram panchayat (GP) is located (Figure 1) in the downstream of the Durgapur barrage on the river Damodar in Burdwan District. It is situated in the north-central portion of the Bhatar Block. Total area of the GP is 4013 hectares. The longitudinal extension of this GP is from $87^0 49'24''$E to $87^0 54'36''$E and latitudinal extension is from $23^0 26'$ N to $23\ ^0 30'$ N.

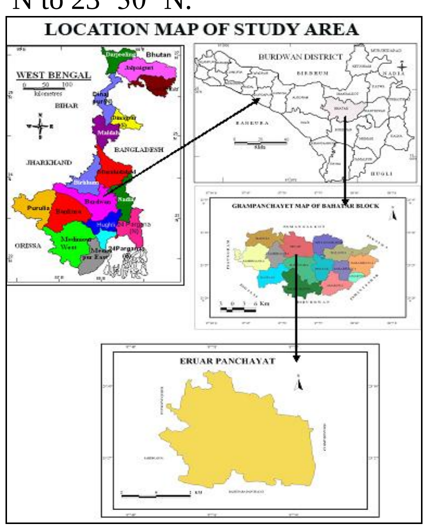

Figure 1: Location map

LULC Pattern of the Study Area

Eruar is a panchayat where over 80 per cent of the population is directly or indirectly engaged in agriculture pursuits. The land use pattern of the study area may be indicated as -a) Agricultural land b) Area not available for cultivation. c) Culturable waste land and d) Forest land. According to the census of India (2001), out of the total geographical area of 4013 hectares, the land of agricultural use was estimated at 3269 hectares or over 81 per cent of the total reported area. Land put to not available for cultivation at 715 hectares or 18% of the total reporting area. Around 29 hectares or 0.7 % of the total area was under culturable waste land. It should be mentioned that, according to official statistics there was zero (0) forest land in 2001. Surface water bodies are considered as very important LULC of the study area and it comes in the category of Area not available for cultivation. As the study is mostly agricultural area, so any change in this sector can be considered as key to the change in surface water bodies. As surface water bodies are very important land features for sustainability and ecological balance, special attention has been paid to evaluate the change in surface water bodies.

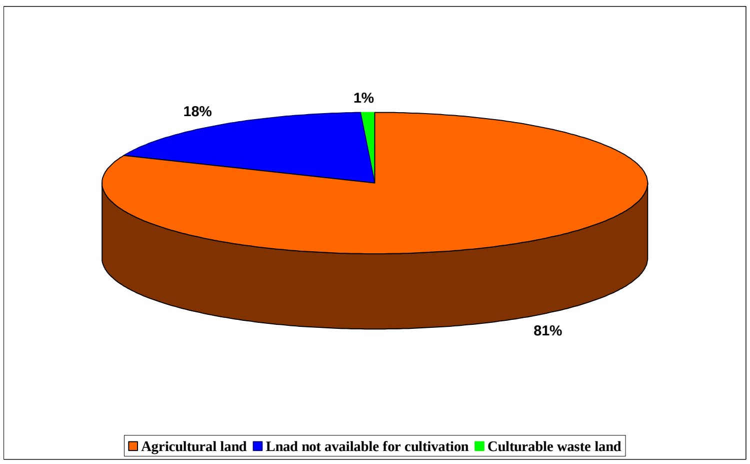

Figure 2: LULC Pattern of Eruar GP, Source: Census of India, 2001

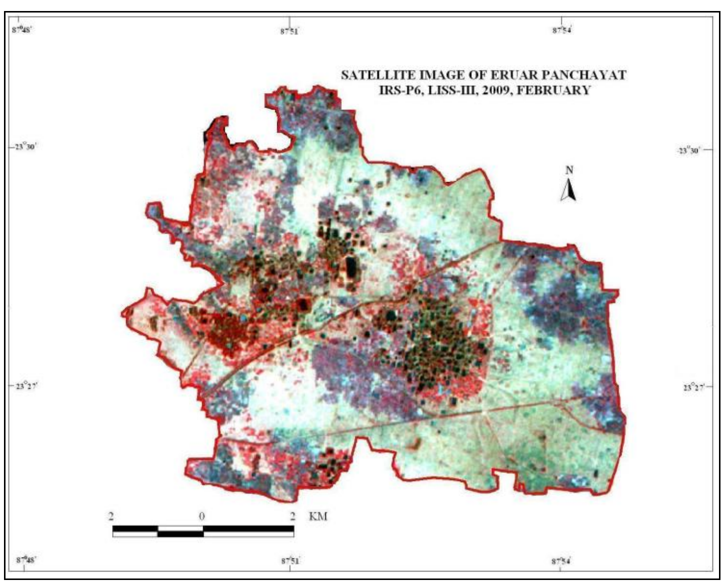

Figure 3: Satellite Image of Eruar Panchayat (IRS-P-6, LISS-III data, 2009)

Surface Water Bodies

Surface water sources of the study area are categorized as rivers, standing water bodies (ponds and tanks), DVC canal and seasonal wetlands. The main sources of surface water of the block are discussed below.

Rivers, Canals and Ponds

There is no any remarkable significant river in this GP. Only a diminutive part of Kunur River (1.65 km) is under Eruar panchayat. A good network of DVC canal is present here and flowing over the whole area of the GP. Total length of DVC canal under this area is 8.17 km. Canal can be an effective source of irrigation in this mouza because low level relief and deep fertile soils are present here.

In this panchayat, there are around 282 ponds and tanks (2009). Tanks may play a very important role in supplying water to this area. The study area partially depends on tanks for irrigation.

A significant observation of the present study is that the surface water body of the panchayat in terms of area and number is decreasing with increasing agricultural land. The total number of surface water body of the GP has decreased from 324 to 282 or above 12 % during the 1974-2009.On the other hand during 1971-2001, the GP experienced above 20 % increase of agricultural land.

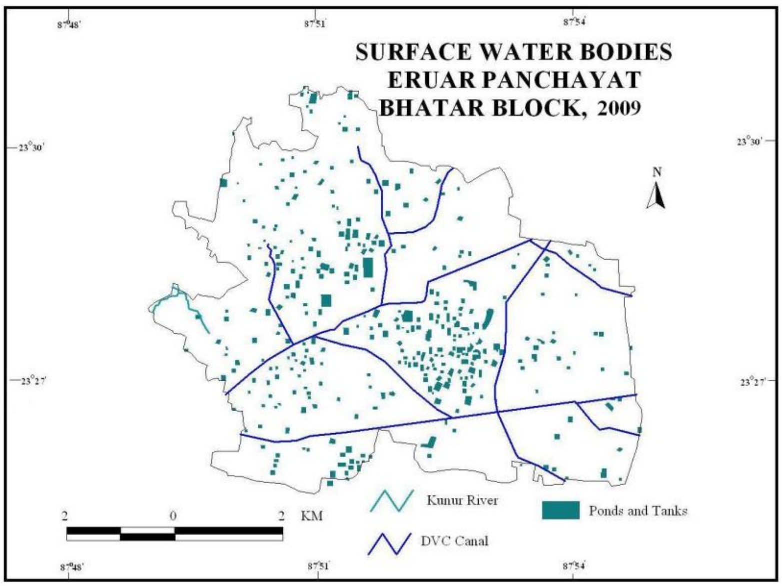

Figure 4: Surface Water Bodies, Eruar Panchayat
Source: Satellite Image (IRS-P6, LISS-III, data, 2009) and field survey

Therefore, attempt will be made in this study to find out the change of LULC and surface water resources of the Eruar panchayat. At the same time we want to predict possible changes that might take place in this status in future using Spatial Markov Model.

MATERIALS AND METHODS

Changing LULC: Use of MRC

With the above condition in the environment, we tried to observe the LULC changes in the Sripur mouza, inside the Eruar panchayat. To study the pattern of LULC change using MRC in the Sripur mouza, 1928 Cadastral maps, 1974 Topographical map (73 M/15), 2009 Satellite image(IRS P6,LISS-III data) have been used and vast field survey in 2010 has been done. In the GIS environment we have generated data for MRF study of changing LULC. The mouza, in each time period, has been overlaid by 50m X 50m grid. The entire map area was divided in to 1740 cells or squares or grids. Each square was then categorized into different land use category.

The total land of the mouza has been classified into six category land use, e.g. agricultural land, surface water bodies, settlement area, fallow land, forest land and road network (Figures 5, 6 and 7). After that,

we club the pure water bodies as type-I land, agriculture and settlement as type –II lands, and forest land, fallow land and road area jointly considered as mixed land use or type-III lands. The grids were then identified by the category it was in 1928 and the category it moved to in 1974, similarly the category it was in 1974 and moved to in 2010. This transformation can be summarized in the way of cross tabulation as Table no: 1 which is the operational basis of the MRF (Markov Random Function).
Considering the number of squares in each cell of the cross tabulation as N_{ij} Number of squares belonging to category 'i ' in initial period and category 'j' in the following period, we have the following
$N_i^0 = \Sigma j\ N_{ij}$ and $N_i^1 = \Sigma\ i\ N_{ij},$
Where,
N_i^0 and N_{i1} are number of squares belonging to type 'i' in primary and final stage respectively.
Currently from this cross tabulation and transition matrix we can calculate transition probability matrix such that term P_{ij} defines the probability that a cell belonging to category 'i' in the initial period transformed to category 'j' in the second period. P_{ij} can be obtained as N_{ij}/N_i^0. This probability matrix may be termed as TP.
Therefore if the matrices representing numbers of cells/grids in every category in initial stage is specified by
$N^0 = [N_1^0, \ N_2^0, N_3^0]$, and that in the next period is given by
$N^1= [N_1^1, \ N_2^1, N_3^1]$; then
$N^1= N^0.\ TP$
[Where N_1, N_2 and N_3 represent to Type I, Type II and Type III land respectively]
If this transition continues at the same rate then the numbers of cell of different land use category in third period can be calculated as
$N^2= N^1.\ TP$
$=N^0.TP.TP$
$= N^0.TP^2$
TP^2 is referred to as 2 period transition probability. To attain steady state we have to obtain such as transition probability matrix. So that the number matrix remain unaltered even after n periods, this can be presented as
$N^{N+1} = N^nTP = N^n$
or $N^n[TP-1] = 0$
or N^0 (TP)n[TP-1] =0………..(A)
To determine steady state our table is to obtain TP^n and thereby obtain the steady state numbers of cells in each category. This is done by solving equation (A) and obtaining Eigenvectors for TP.

RESULTS AND DISCUSSION

Using above mentioned formulas, the retention, gain and loss probabilities were calculated based on the LULC data over the time from 1928 to 1974 and 1974 to 2010 (Table 1) respectively and the transition probability matrix was constructed (Table-2 and 3). While the retention probabilities were listed along the main diagonal, loss probabilities were inserted in the appropriate rows cells of matrix and gain probabilities were inserted in the appropriate column cells of the matrix. It could be seen from table 2 that the water bodies retained its area by 76 per cent and the remaining area has been moved to type II land (21 per cent) and type III land (2 per cent). Type II land has gained 58 per cent of the area from type III land and 21 per cent from type I land. It is also seen that type II land retained its own area by 94 % during 1928 to 1974. Type III land had mostly lost its area to type-II land (58 per cent), and retained its area by only 39 % in 1974 compared to 1928. It has been found from the table 4 that the LULC has changed significantly over the period from 1928 to 1974 in Sripur mouza. During this period, number of cells/grids of pure water bodies (Type I land) declined from 360 to 294, declining by 18 per cent. If the transition probability remains unaltered, after 1 period (in this case 1 period= 1974-1928=46 years) i.e. in the year 2020 it would drop by another 89 units or 30 percent and in third period i.e. in the year 2066 the number of cells of water bodies would be 176. During 1928 to 1974, number of cells of type II land (Agriculture and Settlement) increased from 1195 to 1311 or increased by 10 percent and mixed land decreased by 27 per cent, the decrease quantity amount to 185 to 135. After 1 period, type II land would increase to 1420 or increased by 8 % and at the same time type III land will be 115, which is 15 % short than the year 1974. Using LULC data of 1928 and 1974, we have also obtained the steady state. Table-4 shows that, at the steady state we will have just 91units type I land, 1531units type II land use cells and 119 units type III land use cells.

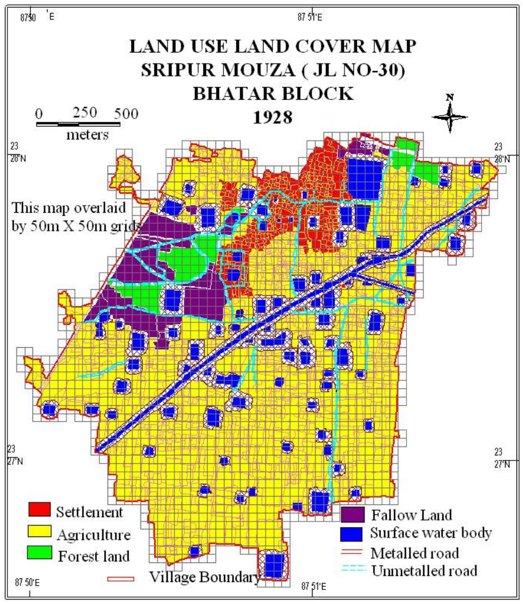

Figure 5: LULC map of Sripur mouza, 1928, Source: Cadastral maps

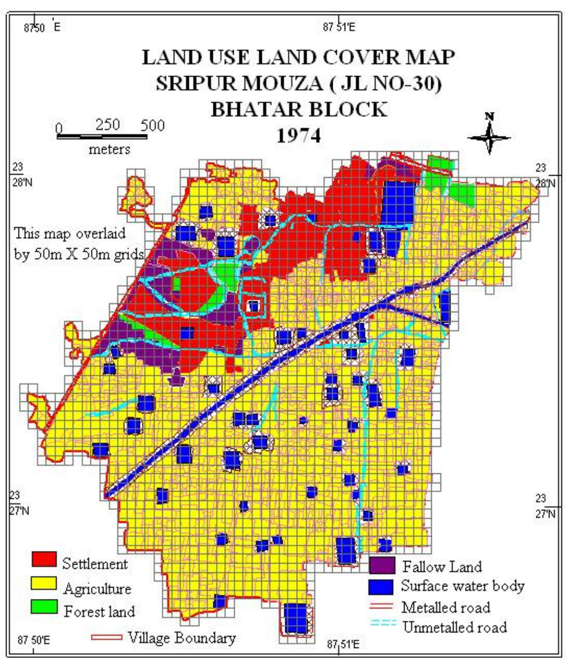

Figure 6: LULC map of Sripur mouza, 1974, Source: Topographical map (73M/15)

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Table 1: LULC Change Transitional Matrix of Sripur Mouza, 1928-2010(Number of cells covered by different LULC)

		1974						**2010**			
Distribution of Cells						**Distribution of Cells**					
		Type-I (Water body)	**Type-II(Agri & Settlement)**	**Type-III (Mixed)**	**Total**			**Type-I (Water body)**	**Type II(Agri & Settlement)**	**Type-III(Mixed)**	**Total**
	Type-I (Water body)	275	77	08	360		**Type-I(Water body)**	195	90	09	294
1928	**Type-II (Agri & Settlement)**	13	1127	55	1195	1974	**Type-II(Agri & Settlement)**	15	1282	14	1311
	Type-III (Mixed)	06	107	72	185		**Type-III (Mixed)**	04	112	19	135
	Total	294	1311	135	1740		**Total**	214	1484	42	1740

Source: Authors' Calculation

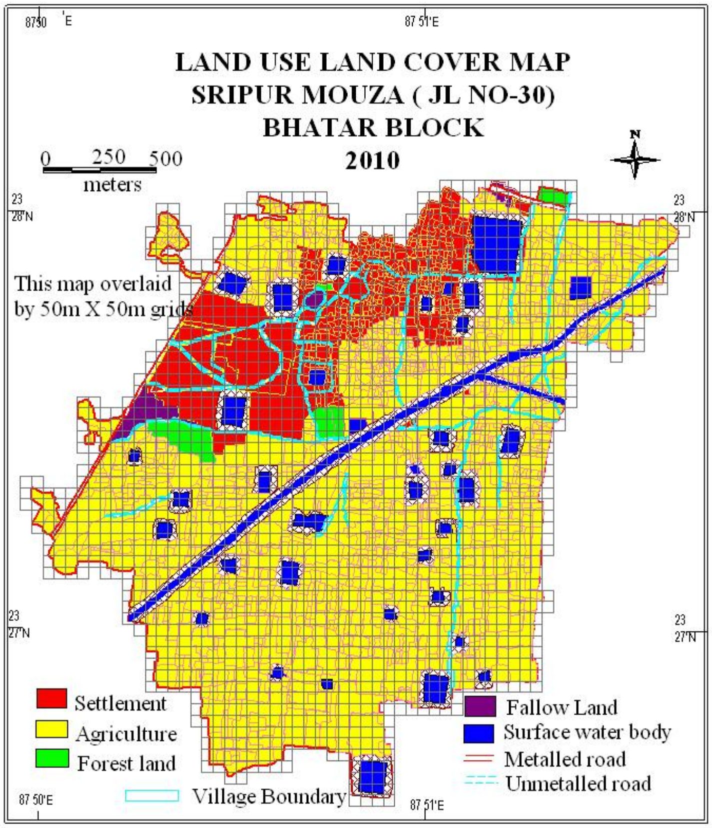

Figure 7: LULC map of Sripur Mouza, 2010. Source: Field Survey

Table 2: Probability Matrix- Markov Chain Analysis, 1928 to1974

		1974		
		Type-I Land	**Type-II Land**	**Type-III Land**
1928	**Type-I Land**	**0.76**	0.21	0.02
	Type-II Land	0.01	**0.94**	0.05
	Type-III Land	0.03	0.58	**0.39**

Source: Authors' Calculation

Table 3: Probability Matrix- Markov Chain Analysis, 1974 to 2010

		2010		
		Type-I Land	**Type-II Land**	**Type-III Land**
1974	**Type-I Land**	**0.66**	0.31	0.03
	Type-II Land	0.01	**0.98**	0.01
	Type-III Land	0.03	0.83	**0.14**

Source: Authors' Calculation

Table 4: LULC change and its future state of Sripur mouza- spatial modelling using Markov Chain (Estimation based on the data of 1928 to1974)

	No. of Cells Covered by			
Year	**Type-I Land (water body)**	**Type-II Land (Agri& Settlement)**	**Type-III Land (Mixed)**	**Total**
1928	360	1195	185	1740
1974	294	1311	135	1740
2020#	205	1420	115	1740
2066#	176	1450	115	1741
Steady State#	**91**	**1531**	**119**	**1741**

Note: # indicates estimation by Markov Modelling.
Source: Authors' Calculation

Table 5: LULC change and its future state of Sripur mouza- spatial modelling using Markov Chain (Estimation based on the data of 1974 to2010)

	No. of Cells Covered by			
Year	**Type-I Land (water body)**	**Type-II Land (Agri& Settlement)**	**Type-III Land (Mixed)**	**Total**
1974	294	1311	135	1740
2010	214	1484	42	1740
2046#	125	1590	25	1740
2082#	102	1614	24	1740
Steady State#	**59**	**1658**	**23**	**1740**

Note: # indicates estimation by Markov Modelling
Source: Authors' calculation

During the period 1974 to 2010, the transition probability matrix of LULC change of the study area is presented in the table 3. During this period, Type I land retains its area by 66 % and rest number of cells of this land moved to type II (31%) and type III (03%). Type II land has gained 83 per cent of the area from type III land and 31 per cent from type I land; on the other hand it retained its own area by 98 %. Type III land had lost its 83 % of cells to agriculture and settlement area (Type II). Table 5 shows that, during 1974-2010, number of cells of Type I land declined from 294 to 214, declining by 27 per cent. If this rate remains unaltered, after one period (2010-1974=36 years), i.e. by the year 2046, it would deplete to 125 or 42%. Number of cells of type II land increased from 1311 to 1484 or increased by 13 per cent and in 2046, it would increase to 1590. At the same time, mixed land decreased by 68 per cent, the decrease quantity amount to 135 to 42 and in 2046, it will be only 25. Using the data of 1974 and 2010, long run stable equilibrium state has been obtained, where the numbers of cells of each category converge. If this rate continues, at the steady state we will have 59 type I land use cells, 1658 tye-2 land use cells and only 23 mixed land use cells (Table 5).

Thus LULC change detection in Sripur mouza for the period of 1928-2010 is divided in to two phases, 1928-1974 and 1974-2010. The analysis is done with the help of MRC model, which shows the land amount for type I, type III has decreased in both of the phases, where type II records increase in the same periods. It is recommended from the calculation nearly 600 years is required to achieve the steady state condition if the LULC change in first period is concerned. The number of cells under type I, type II and type III land use would be 91, 1531, and 119 respectively. On the other hand the achievement of steady state condition requires nearly 400 years in phase two (1974-2010) as per the present rate of LULC change. The cell number of type I, type II and type III land use would be 59, 1658 and 23. It has been noticed that the change of land use rate is much more in second phase (1974-2010) than the first phase. Finally it can be concluded that the expansion of agriculture and settlement area (Type II) is responsible for depletion of surface water resource and mixed land use category. The result of the analysis indicates that the annual rate of depletion of water body is showing positive trend over time.

LULC Change and Depletion of Surface Water Resources

Changes in LULC have significant impact on surface water resource depletion. Intensive field studies were conducted to record the nature of change of surface water body of the area in to other land use category and the detail is given in Table 6.

Table: 6: **Transformation of Surface Water Bodies to other LULC of Sripur mouza**

Plot Number	Transfer to	Plot Number	Transfer to	Plot Number	Transfer to
73	Settlement	761	Agriculture	1546	Agriculture
143	Settlement	782	Settlement	1547	Agriculture
225	Settlement	796	Agriculture	1558	Agriculture
285	Settlement	798	Agriculture	1573	Agriculture
305	Settlement	811	Agriculture	1602	Agriculture
345	Settlement	828	Agriculture	1646	Agriculture
362	Agricultural	846	Agriculture	1643	Agriculture
398	Agriculture	847	Agriculture	1645	Agriculture
647	Agriculture	849	Social Forest	1795	Agriculture
562	Settlement	876	Agriculture	1796	Agriculture
652	Agriculture	1010	Agriculture	1820	Agriculture
688	Agriculture	1241	Agriculture	1840	Agriculture
691	Agriculture	1276	Agriculture	1940	Agriculture
703	Agriculture	1502	Agriculture	2016	Agriculture
760	Agriculture	1534	Agriculture	2293	Agriculture

Source: Field Survey

The rate of depletion of surface water bodies was not consistent all over the assessment period. To realize the rate of depletion of surface water resource in different time the transition probabilities may be derived as follows:

Probability that a given cell was water body in 1928 and remained so in 1974, known as the one step transitional probability, is specified by:

$P_{ii} = P\ \{X_t = ai|X_{t-1} = a_i\} = 275/360 = 0.76$

For the next period, i.e. in between 1974-2010, this one-step transitional probability, is given by 195/294 = 0.66.

Similarly, Probability that a specified cell was not a water body in 1928 but was transformed to a water body in 1974 is specified by:
P_{ij} = P {X_t =a_j|X_{t-1}=a_j} = 19/1380 = 0.01 [13+6=19, where, 13 cells came under the category of water body (type I land) from type II land and 6 from type III land, 1380(1195+125) denotes total number of cell under type II and type III land in the year 1928]
The same probability for the 1974-2010 periods is specified by: 19 /1446 = 0.01.
Thus the net depletion rate was 23% {1-(0.76+0.01)} during the 46 years in between 1928 to 1974, and in the next 36 years (1974-2010) it was 33 % {1-(0.66+0.01)}. This result obviously indicates a much quicker rate of depletion of surface water bodies during 1974-2010. It is also found from the Table 5 that in the year 2046, the number of water bodies would deplete to 125, i.e. by 58 % of present number.
There is thus clear indication of unsustainable changes in LULC in the area concerned, where extension of agricultural activities and settlement area is leading to depletion of surface water bodies.

Conclusion

Thus the region has experienced extensive expansion and intensification of agricultural land and settlement area and reduction of surface water bodies in the final quarter of the last century and first decade of the present century. Agricultural activities of this region have increased in terms of area and percentage. The population of the Eruar panchayet has also been doubled in last 40 years. Consequently, demand of food has increased. Thus population pressure on per unit of agricultural land is rising as population is dynamic and land is of static nature. It was recorded during field visits that the sideward part of different water bodies were leveled and used as agricultural land and only central part of the water body was providing water. So, it is clear that the massive spreading out of human activities have required change of land under water bodies and marginal lands into other types of land uses, mainly agriculture and settlement area of the region. It has been estimated using Markov Random Chain (MRC) method that in next 36 years, the number of surface water bodies (type I land) will deplete by 42% and type II land (agriculture and settlement) will increase by 7% in the study area. Due to excess withdrawal of surface water from existing water bodies for Rabi cultivation, most of the ponds of the region are drying up before beginning of summer season. The cultivators of the region are using those dried up ponds for agricultural purpose. There is thus a grim trend to switch the surface water bodies into agricultural field. Thus LULC change of the region is connected with depletion of presented water bodies. Under such situation, some proper measures must be taken so that the LULC change and water resource of the region remains sustainable in the long run. With growing water scarcity, tank rejuvenation may be an important way in which water can be conserved for both surface and groundwater irrigation. The situation also invites in for alternative cropping pattern and alternative cropping methods.

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