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Harsimrat Kaur Gill

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Research Article

LAND USE AND LAND COVER IN PUNJAB SATLUJ FLOODPLAIN (INDIA): A STATISTICAL SURVEY THROUGH LOSS-GAIN ALGORITHM

Harsimrat Kaur Gill

Center of Advanced Study in Geography, Panjab University, Chandigarh-160014, India

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ABSTRACT

'Land use and land cover change' is a dynamic process, its magnitude and direction of change is highly vulnerable to human actions. *Human beings* are the core agent that promotes this dynamic landscape transformation. These conversions occurred due to the expansion of human employment on land at the cost of natural cover, which simultaneously faced disappearance. This journey of landscape transformation includes expansion and disappearance of land use and land cover categories with reference to different points in time. In Punjab Satluj floodplain this changing transformations can be noticed from the changing land cover to land use ratios, which was 54:46 during 1975 and reduced to 12:88 for 1989 and this pattern continued for succeeding years with 8:92, 7:93 and 5:95 for 2000, 2005 and 2012 respectively. Land cover categories lost their land, whereas land use categories gained it. This gain loss algorithm highlights the need of setting the threshold limit of land use and land cover transformations.

INTRODUCTION

Land use and land cover change takes place over time. Land use is a description of how people utilize the land, whereas land cover refers to the physical and biological cover over the surface of land (Ellis and Pontius, 2010). Whole landscape is covered under either land use or land cover. Changes in land use and land cover (LULC) pattern depict the development and modification status of landscape. This change can be a natural process, which occurs at an 'ecologically acceptable pace'. Human interventions over the natural landscape have drastically modified and transformed the natural cover (Turner *et al*., 2007; Lambin *et al*., 2001; Olson *et al*., 2008; Gibbes *et al*., 2009; Mallinis *et al*., 2011; Mendosa *et al*., 2011; Radcliffe, 2012; Strand *et al*., 2012; Sohl *et al*., 2012; Classidy *et al*., 2013; Stoebner *et al*., 2014; Kane *et al*., 2014 and Grecchi *et al*., 2014). The pace, intensity and magnitude of this change depends on the site specific attributes such as elevation, water availability, soil fertility, climatic conditions (Dale *et al*., 1993 and Wear and Flamm, 1993) and socio economic conditions, which involve human growth and pressure, government policies and infrastructural development (Turner *et al*., 1996; Barbier, 1997; Lambin *et al*., 2001; Priess, 2001; Moseley, 2004; Rudel, 2005 and Munroe *et al*., 2014), that create imbalances through the conversion of natural landscape (Lee *et al*., 1995; Verburg *et al*., 2009 and Verburg *et al*., 2013).

A river is a natural attraction for settlement – be it agriculture, village or urban settlement; the Satluj River is no exception (figure 1). The floodplain of this river offers immense scope for development. This area is attributed with physical unity of resources, which makes floodplains attractive for regional development (Wengert, 1957). This process of development includes controlling the river through dams, river bandhs and barrages, which reduce the downstream flow of water (Kaur and Brar, 2013). Controlling the river has opened up possibilities of colonizing the floodplain. Most of the wetlands were drained to make way for agriculture. The absence of the overpowering presence of the river and its flood events made it increasingly attractive for agriculture and settlement. Human initiatives through government policies and plans, promotion of agricultural research and development of infrastructure and technology expanded and intensified the agriculture and built up area expansion at the cost of natural cover.

**Corresponding author: Harsimrat Kaur Gill*
Center of Advanced Study in Geography, Panjab University, Chandigarh-160014, India

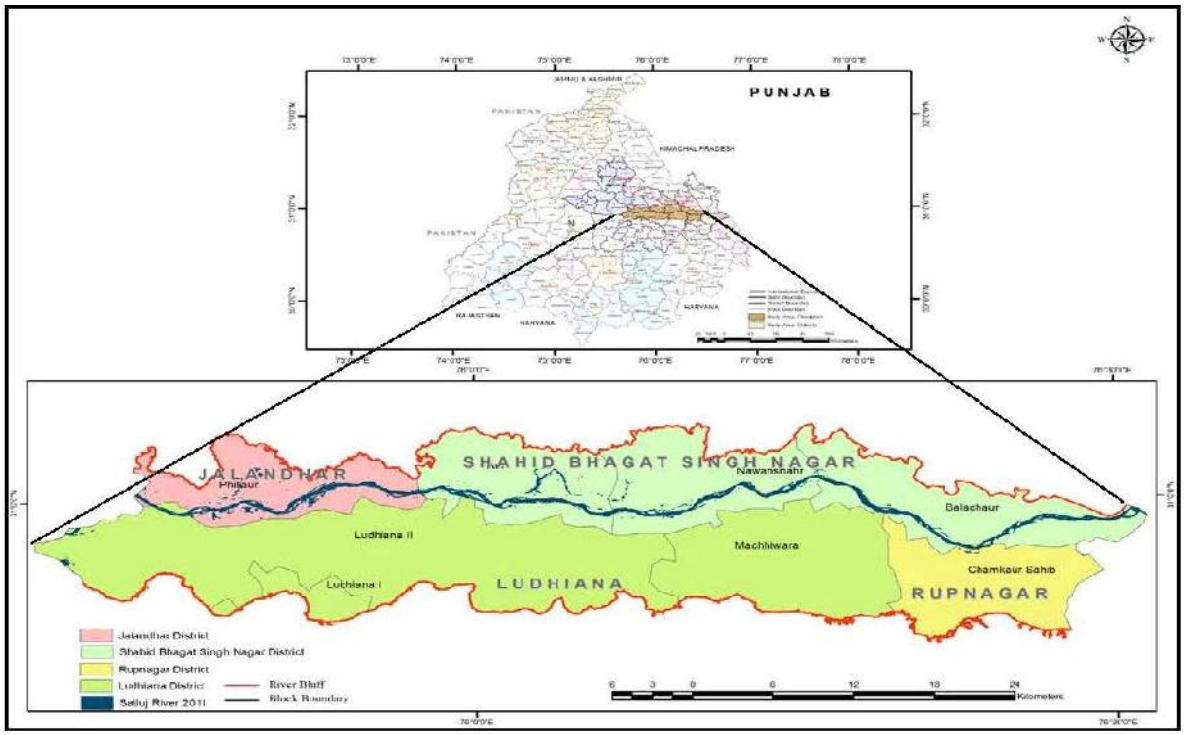

Figure 1 Study Area: Punjab Satluj Floodplain Study Area The area selected for conducting the present study lies in the floodplain of the Satluj, stretching from 30°52' N to 31°03' N and 75°39' E to 76°30' E latitudes and longitudes respectively. This natural entity covers 104275.1 hectares, which includes part of Phillaur tahsil of Jalandhar district, Nawanshahr and Balachaur tahsils of Shahid Bhagat Singh Nagar district, Rupnagar tahsil of Rupnagar district and Ludhiana West, Ludhiana East and Samrala tahsils of district Ludhiana, Punjab (India).

Here loss gain algorithm has been used to calculate the to-from pattern of land use and land cover categories.

METHODOLOGY

Land use and land cover maps generated from the 1975, 1989, 2000, 2005 and 2011 satellite imageries. Unsupervised classification technique has been applied for preparing land use and land cover transformation maps.

Methodology adopted for preparing the data set for land use and land cover trend analysis has been shown through figure 2.

Data set has been formed, while employing following steps:

- Prepared land use and land cover pattern maps for 1975, 1989, 2000, 2005 and 2011 are overlaid for analyzing the land use and land cover trends.

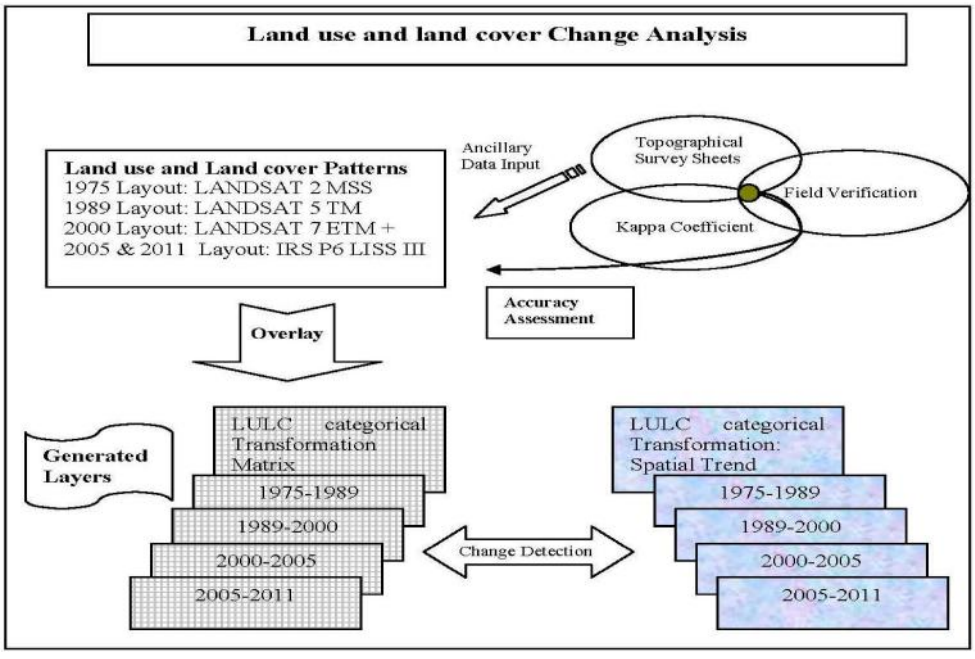

Figure 2 Methodology used for Analyzing Land use and Land cover Change

- Generated figures are combined in the matrix form for comparative analysis. This matrix helps in interpretation of the category wise transformation through to and from procedure calculated from *loss-gain algorithm.*

  All the main diagonal figures represent area with no change and off diagonal figures indicate change. Rows represent LULCC origin/ source or *change from* figures and columns indicate LULCC destination or *change to* figures.
- Land use and land cover category wise transformation map has been formed, while constituting categories having no change, less than 1% change and more than 1% change.

RESULTS AND DISCUSSION

Land use and land cover change: categorical transformation analysis

Categorical modification and transformation of individual LULC class framed in transformational matrix exhibits the change and no change land use and land cover at disaggregate scale with respect to spatially explicit modeling approach.

LULC transformational analysis: 1975-1989

In the year 1975 the ratio of land cover to land use was 54: 46 (table 1). In 1989 this ratio became highly imbalanced in favor of land use with 12: 88. The clear dominance of human activities over the floodplain became apparent.

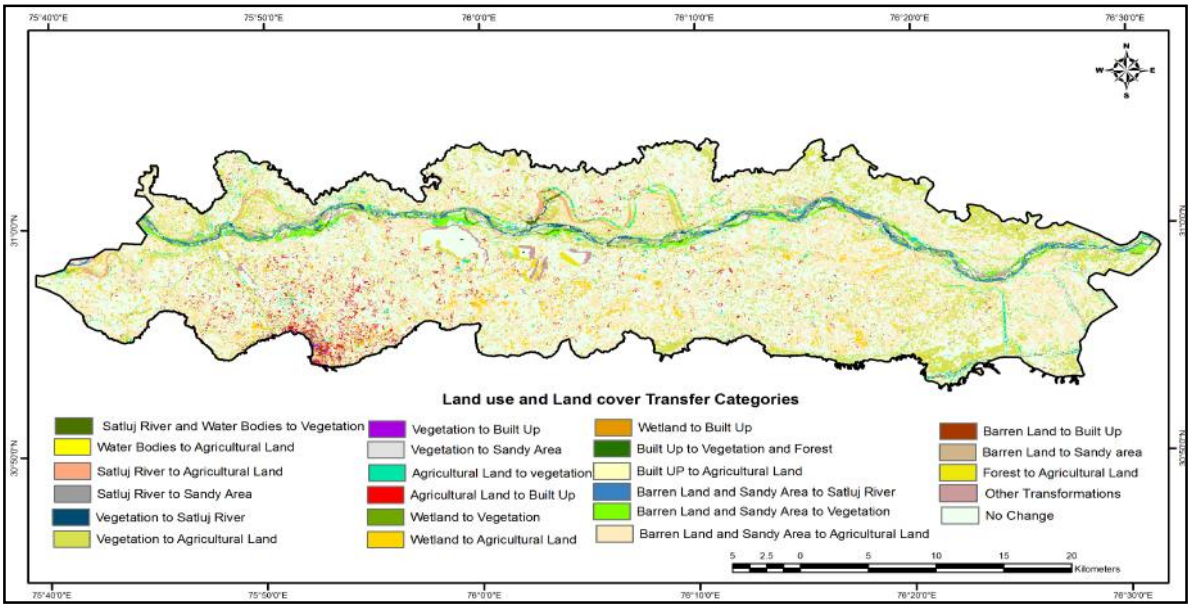

Figure 3 Land use and Land cover Change in Punjab Satluj Floodplain from 1975 to 1989

Table 1 Punjab Satluj Floodplain: Land use and Land cover Transformational Matrix 1975-1989

Categories	Water Bodies	Satluj River	Vegetation	Agricultural Land	Wetland	Built Up	Barren Land	Forest	Sandy Area	Total Transfer: Loss	Year 1975 Total
Water Bodies	65.17 (30.87)	0.35 (0.17)	57.5 (27.24)	85.1 (40.31)	0.98 (0.46)	0.7 (0.33)	0.1 (0.05)	0	1.21 (0.57)	145.94 (69.13)	211.11
Satluj River	5.82 (0.4)	283.47 (19.24)	371.57 (25.23)	535.95 (36.39)	0	3.86 (0.26)	3.46 (0.23)	2.17 (0.15)	266.67 (18.1)	1189.5 (80.76)	1472.97
Vegetation	14.06 (0.09)	233.86 (1.44)	1327.14 (8.15)	14050.87 (86.24)	34.63 (0.21)	259.56 (1.59)	25.06 (0.15)	59.29 (0.36)	288.03 (1.77)	14965.36 (91.85)	16292.5
Agricultural Land	2.6 (0.01)	199.47 (0.42)	1389.05 (2.95)	43719.06 (92.91)	151.93 (0.33)	955.46 (2.03)	129.27 (0.27)	133.28 (0.28)	376.99 (0.8)	3338.05 (7.1)	47057.11
Wetland	0	1.38 (0.08)	45.11 (2.78)	1499.99 (92.47)	9.05 (0.56)	43.85 (2.7)	0.41 (0.03)	13.61 (0.84)	8.7 (0.54)	1613.05 (99.44)	1622.1
Built Up	0	0.29 (0.06)	8.7 (1.85)	433.76 (92.39)	0.52 (0.11)	16.6 (3.54)	0.12 (0.03)	6.69 (1.42)	2.82 (0.6)	452.9 (96.46)	469.5
Barren Land	2.1 (0.01)	607.57 (1.88)	1677.74 (5.18)	28339.33 (87.51)	71.15 (0.21)	679.43 (2.1)	68.16 (0.21)	148.69 (0.46)	790.1 (2.44)	32316.11 (99.79)	32384.27
Forest	0	0.17 (0.01)	11.37 (0.82)	266.37 (19.25)	0.7 (0.05)	6.46 (0.47)	0.46 (0.03)	1097.19 (79.29)	1.04 (0.08)	286.57 (20.71)	1383.76
Sandy Area	0	552.35 (16.34)	934.43 (27.63)	978.9 (28.95)	2.48 (0.07)	11.97 (0.35)	2.42 (0.07)	4.61 (0.14)	894.58 (26.45)	2487.16 (73.55)	3381.74
Total Transfer: Gain	24.58 (27.38)	1595.4 (84.91)	4495.47 (77.21)	46190.27 (51.37)	262.39 (96.66)	1961.3 (99.16)	161.3 (70.29)	368.34 (25.13)	1735.6 (65.98)	56794.64 (54.47)	
Year: 1989 Total	89.75	1878.91	5822.61	89909.33	271.44	1977.89	229.46	1465.53	2630.14		104275.1

Values are in hectares and parentheses values represent percentage

Source: Data extracted from LANDSAT MSS 1975 and LANDSAT TM 1989 Satellite Images

Increasing human use were reflected through the positive change in agricultural and built up area. This spatial expansion of land use has been done at the cost of natural scape, which included vegetation, wasteland, wetland and water bodies. During this period Satluj River area and forest cover increased by 405.94 hectares (27.55%) and 81.27 hectares (5.9%) respectively (table 1 and figure 3). Expansion of area under Satluj River happened due to the release of water from Bhakra Dam (Ray, 2010). In these fourteen years 54.47% total land use and land cover transformation was noticed (Table 1).

Categories that underwent maximum loss to other categories included barren land (99.79%), wetland (99.44%), built up area (96.46%), vegetation (91.85%), sandy area (73.55%) and water bodies (69.13%). Less than quarter transformation for other categories was recorded in agricultural (7.1%) and forest area (20.71%). Dominant share of each land cover has been transformed to agricultural area such as 88% share of barren land, 92.47% of wetland, 86.24% of vegetation, 40% of water bodies, 36% of Satluj River, 30% of sandy area and 19% of forest area transformed and utilized for agricultural purposes. Spatial expansion of built up area was contributed by the transformation of 2.7% of wetland, 2.1% of barren land, 2.03% of agricultural land and 1.59% of vegetated area. Decreased spatial distribution of vegetation cover happened due to its transformation to other categories, which included 86% transformation to agricultural land, 1.77% to sandy area, 1.59% to built-up area and 1.44% to Satluj River. Barren land reflected 99.29% reduction in spatial extent with maximum share went to agricultural land. Vegetation cover and sandy area had been found on 5.18% and 2.44% land respectively near the main channel, which was earlier categorized as barren. Sandy areas reduce by 751.6 hectares (22.22%). Sandy area lost its 27.63% and 16.34% area for vegetation and Satluj River respectively. Wetland categorized as seasonal and perennial faced reduction in their spatial distribution with 84.76% and 73.48% respectively. Its prominent transformation went to agricultural land followed by vegetation and built up area as reflected from table 1and figure 3.

LULC transformational analysis: 1989-2000

Statistical variation during this eleven year revealed LULC transformation in similar direction, but at distinct magnitude. There was increase in agricultural land and built up area with 2320.4 hectares (2.58%) and 1827.83 hectares (92.41%) respectively and significant reduction in spatial extent had been noticed in the vegetation, wetland, forest, riverine and sandy area with 2135.17 hectares, 55.7 hectares, 102.47 hectares, 358.22 hectares and 1279.63 hectares respectively (figure 4). Area under barren land was totally transformed and maximum transfer i.e. 96% went to agricultural land, followed by 2.31% to built up area, 1% to wetland, 0.3% to Satluj River, 0.2% to vegetation, 0.06% to water bodies, 0.03% to sandy and forest area (table 2).

Area under wetland category was reduced by 55.7 hectares (20.52%). Its 96% share went to agricultural land, 1.46% to built-up area and 0.37% to vegetation. 85% sandy area was transformed to other categories. Its 13% area spread along the Satluj river channel got transformed and becomes part of this category. Satluj River reflected diminishing trend in their spatial distribution with 358.22 hectares reduction. Its 33% share went to agricultural land, 26% to vegetation and 13% to sandy area. 72% vegetation cover transformed to other categories and its spatial extent reduced by 36.67%. Its 57% share was transferred to agricultural land, 7% to Satluj River, 6.64% to sandy area, 1% to built up area, 0.26% to water bodies, 0.14% to wetland and 0.05% to forest area. Built up area was increased by 1827.83 hectares (92.41%). This spatial addition happened with 2.75% contribution of agricultural land, 2.31% of barren land, 1.46% of wetland, 0.68% of vegetation, 0.14% of sandy area, 0.06% of forest and 0.01% of Satluj River. Although its 35% area was transformed, with its 34.43% conversion to agricultural land, 0.66% to vegetation, 0.12% to wetland, 0.06% to forest and sandy area and 0.03% to Satluj river (Table 2 and figure 4).

Water bodies incorporating surface water increased by 12.45 hectares (13.87%), which occurred due to its less i.e. 17.65% transformation for other categories. This category was benefited by the 0.26% share of vegetation, 0.06% of barren land and 0.01% of agricultural land. Forest area was reduced by 102.47 hectares (7%). 9.44% land under forest cover was transformed to other categories. Its 8.97% share went to agricultural land, 0.38% to vegetation, 0.06% to built-up area, 0.02% to Satluj River and 0.01% to wetland. Agricultural area expanded as significant part of each category got transferred into this category. Although agricultural land was also transformed to other categories with 4.63% transformation and its 2.75% share contributed to built up area, 1% to vegetation, 0.35% to sandy area, 0.27% to Satluj River, 0.22% to wetland, 0.03% to forest area and 0.01% to water bodies (Table 2 and figure 4).

LULC transformational analysis: 2000-2005

Human endeavor towards the resource exploitation can be measured and explicitly noticed through this five year LULC change detection (table 3 and figure 5), which reflects the positive change in agricultural land and built up area with 1353.04 hectares (1.47%) and 151.33 hectares (3.98%) respectively and disastrous implication of this change was depicted from the emergence of barren land with 37.32 hectares spatial expansion, specifically 24.5 hectare area earlier under agricultural land was transformed under this category.

Although, there was also increase in riverine area with 136.98 hectares (9%) due to the breaching of Parichu Lake in 26th June, 2005 (Sharma, 2006). Area covered under sand was also increased with 327.95 hectares (24.28%). Negative change was calculated for vegetation, forest area, wetland and water bodies with 1927.53 hectares (52.27%), 36.12 hectares (2.64%), 31.14 hectares (14.43%) and 11.83 hectares (11.57%) respectively (figure 5). In this period 10.38% land use land cover transformations was noticed for whole study area. 82% vegetation area was transformed to other categories. Its 49.3% area transferred to agricultural land, 16.4% to sandy area, 15% to Satluj River, 0.41% to built up area, 0.36% to water bodies and 0.23% to barren land. Noticeable change was detected in sandy area. 80.63% sandy area transformed to other categories, whereas 36.64% area added to this category from others.

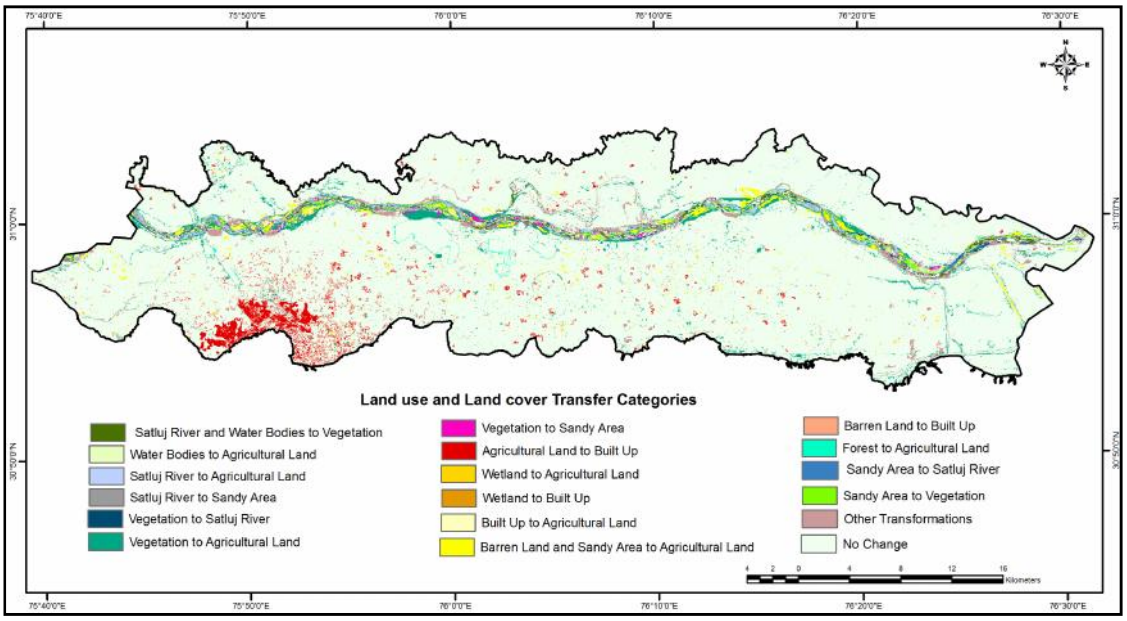

Figure 4 Land use and Land cover Change in Punjab Satluj Floodplain from 1989 to 2000

Table 2 Punjab Satluj Floodplain: Land use and Land cover Transformational Matrix 1989-2000

Categories	Water Bodies	Satluj River	Vegetation	Agricultural Land	Wetland	Built Up	Barren Land	Forest	Sandy Area	Total Transfer: Loss	Year:1989 Total
Water Bodies	73.91 (82.35)	0	14.46 (16.11)	1.38 (1.54)	0	0	0	0	0	15.84 (17.65)	89.75
Satluj River	1.08 (0.06)	524.5 (27.92)	481.97 (25.65)	618.8 (32.93)	0.18 (0.01)	0.28 (0.01)	0	0.91 (0.05)	251.19 (13.37)	1354.41 (72.1)	1878.91
Vegetation	15.41 (0.26)	405.56 (6.97)	1655.34 (28.43)	3309.05 (56.83)	8.18 (0.14)	39.35 (0.68)	0	2.99 (0.05)	386.73 (6.64)	4167.27 (71.57)	5822.61
Agricultural Land	11.68 (0.01)	246.11 (0.27)	892.1 (1)	85748.33 (95.37)	196.98 (0.22)	2473.74 (2.75)	0	30.54 (0.03)	309.85 (0.35)	4161 (4.63)	89909.33
Wetland	0	0	1.01 (0.37)	261.49 (96.33)	4.99 (1.84)	3.95 (1.46)	0	0	0	266.45 (98.16)	271.44
Built Up	0	0.53 (0.03)	13.03 (0.66)	680.97 (34.43)	2.4 (0.12)	1278.55 (64.64)	0	1.28 (0.06)	1.14 (0.06)	699.35 (35.36)	1977.9
Barren Land	0.12 (0.06)	0.69 (0.3)	0.47 (0.2)	220.49 (96.1)	2.22 (0.97)	5.31 (2.31)	0	0.08 (0.03)	0.08 (0.03)	229.46 (100)	229.46
Forest	0	0.22 (0.02)	5.62 (0.38)	131.39 (8.97)	0.18 (0.01)	0.92 (0.06)	0	1327.2 (90.56)	0	138.33 (9.44)	1465.53
Sandy Area	0	343.08 (13.04)	623.44 (23.7)	1257.83 (47.83)	0.61 (0.02)	3.63 (0.14)	0	0.06 (0)	401.49 (15.27)	2228.65 (84.74)	2630.14
Total Transfer: Gain	28.29 (27.68)	996.19 (65.51)	2032.1 (55.11)	6481.4 (7.02)	210.75 (97.68)	2527.17 (66.4)	0	35.85 (2.63)	949.01 (70.27)	13260.76 (12.72)	
Year:2000 Total	102.2	1520.69	3687.44	92229.73	215.74	3805.73	0	1363.06	1350.5		104275.1

Values are in hectares and parentheses values represent percentage.
Source: Data extracted from LANDSAT TM 1989 and LANDSAT ETM 2000 Satellite Images.

It gained 36.64% share of Satluj River, 16.4% of vegetation, 0.27% of agricultural land, 0.06% of built up area and 0.01% of forest area, while land previously under sandy area got transferred to other categories, which included 47.82% to agricultural land, 17.7% to vegetation cover, 14.51% to Satluj River, 0.6% to built up area and 0.01% to wetland. More than half i.e. 56% of Satluj River channel area was transformed to other categories with a prominent share i.e. 37% going to sandy area, 15% to agricultural land, 5% to vegetation, 0.1% to wetland, 0.05% to barren land, 0.01% to forest and built up area. This category was 9% expanded.

During this period 15% of vegetation cover, 14.5% of sandy area and 0.25% of agricultural land was submerged under the Satluj River channel (table 3 and figure 5). 54% built up area was transferred with its 53.71% part was encroached by agricultural land, 0.2% by wetland, 0.1% by vegetation and barren land, 0.06% by sandy area and 0.01% by forest. Built up area was expanded by 3.98%. This category benefited by 2.37% of agricultural land, 0.6% of sandy area, 0.41% of vegetation, 0.18% of wetland, 0.05% of forest and 0.01% of Satluj River. Wetland area decreased by 14.43% and 48% of its area was transferred to other categories, which includes 47% to agricultural land, 1% to vegetation, 0.2% to built up area and 0.01% to forest cover.

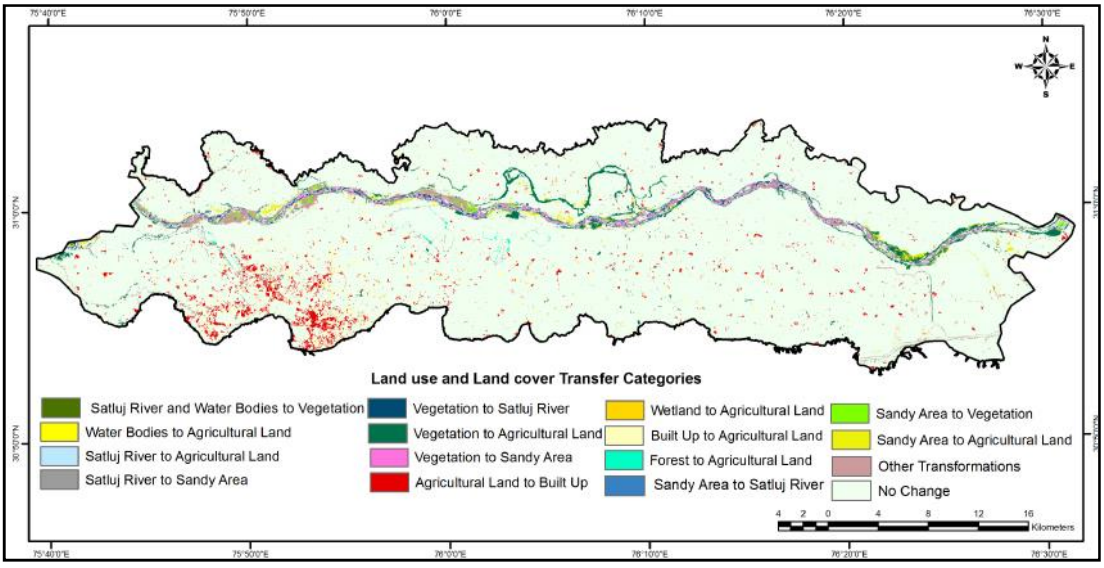

Figure 5 Land use and Land cover Change in Punjab Satluj Floodplain from 2000 to 2005

Table 3 Punjab Satluj Floodplain: Land use and Land cover Transformational Matrix 2000-2005

Categories	Water Bodies	Satluj River	Vegetation	Agricultural Land	Wetland	Built Up	Barren Land	Forest	Sandy Area	Total Transfer: Loss	Year:2000 Total
Water Bodies	69.89 (68.38)	0.04 (0.04)	25.02 (24.48)	7.25 (7.1)	0	0	0	0	0	32.31 (31.61)	102.2
Satluj River	0	667.45 (43.9)	68.98 (4.54)	224.24 (14.74)	1.64 (0.11)	0.14 (0.01)	0.81 (0.05)	0.1 (0.01)	557.33 (36.64)	853.24 (56.11)	1520.69
Vegetation	13.43 (0.36)	561.24 (15.22)	663.89 (18)	1817.77 (49.3)	1.54 (0.04)	15.3 (0.41)	8.32 (0.23)	1.43 (0.04)	604.52 (16.4)	3023.55 (82)	3687.44
Agricultural Land	7.05 (0.01)	232.97 (0.25)	756.98 (0.82)	88658.13 (96.13)	62.09 (0.07)	2188.69 (2.37)	24.48 (0.03)	46.87 (0.05)	252.47 (0.27)	3571.6 (3.87)	92229.73
Wetland	0	0	1.68 (0.78)	102.18 (47.36)	111.48 (51.67)	0.38 (0.18)	0	0.02 (0.01)	0	104.26 (48.33)	215.74
Built Up	0	0.06 (0)	3.57 (0.1)	2044.29 (53.71)	7.57 (0.2)	1743.86 (45.82)	3.71 (0.1)	0.28 (0.01)	2.39 (0.06)	2061.87 (54.18)	3805.73
Barren Land	0	0	0	0	0	0	0	0	0	0	0
Forest	0	0	0.81 (0.06)	83.11 (6.1)	0.1 (0.01)	0.63 (0.05)	0	1278.24 (93.77)	0.17 (0.01)	84.82 (6.22)	1363.06
Sandy Area	0	195.91 (14.51)	238.98 (17.7)	645.8 (47.82)	0.18 (0.01)	8.06 (0.6)	0	0	261.58 (19.36)	1088.93 (80.63)	1350.51
Total Transfer: Gain	20.48 (22.66)	990.22 (59.73)	1096.02 (62.27)	4924.64 (5.26)	73.12 (39.61)	2213.2 (55.93)	37.32 (100)	48.7 (3.67)	1416.88 (84.41)	10820.58 (10.38)	
Year:2005 Total	90.37	1657.67	1759.91	93582.77	184.6	3957.06	37.32	1326.94	1678.46		104275.1

Values are in hectares and parentheses values represent percentage.
Source: Data extracted from LANDSAT ETM 2000 and IRS P6 LISS III 2005 Satellite Images.

Water bodies faced 11.57% spatial reduction with 32% transformation for other categories. Its 24.5% share went to vegetation, 7% to agriculture and 0.04% to Satluj River (table 3 and figure 5). Reserved and protected forest area faced only 6% transformation due to its Government implemented restriction. Agricultural area with 1353.04 hectares increase attributed by the 54% share contribution of built up area, 49% of vegetation cover, 48% of sandy area, 47% of wetland, 15% of Satluj river, 7% of water bodies and 6% of forest area. Agricultural area faced 4% transformation for other categories. Its 2.37% share went to built up area, 1% to vegetation, 0.27% to sandy area, 0.25% to Satluj river, 0.07% to wetland, 0.05% to forest cover, 0.03% to barren land and 0.01% to water bodies (table 3 and figure 4).

LULC transformational analysis: 2005-2011

Land use and land cover transformation was decreased with 1.33% for study area, as it was 10.38% in 2000-2005 and reduced to 9.05% in 2005-2011(table 4 and figure 6). During this interval of time specific negative change of 2571.41 hectares (2.75%) was calculated for agricultural area (figure 6) with its 3.6% spatial extent was turned into built up land. Except agricultural land other categories followed the similar change, but at low magnitude. Categories with negative change included vegetation 49.26% (866.89 hectares), sandy area 1.28% (21.45 hectares), wetland 10.35% (19.1 hectares) and forest area 0.06% (0.73 hectares), where as categories with positive change include built up area 64.15% (2538.64

hectares), Satluj River 55.35% (917.63 hectares) and water bodies 67.04% (60.59 hectares).

bodies, 1% to built up area, 0.1% to wetland and 0.02% to forest area. 67.49% wetland area was transferred to other

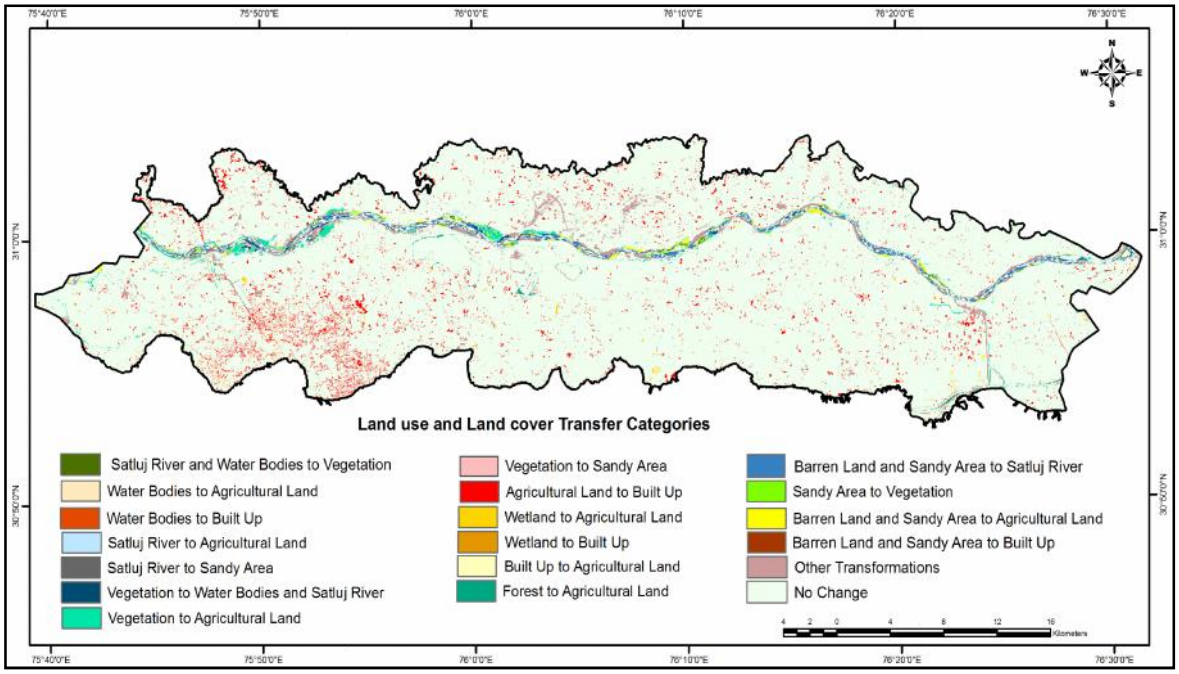

Figure 6 Land use and Land cover Change in Punjab Satluj Floodplain from 2005 to 2011

Table 4 Punjab Satluj Floodplain: Land use and Land cover Transformational Matrix 2005-2011

Categories	Water Bodies	Satluj River	Vegetation	Agricultural Land	Wetland	Built Up	Barren Land	Forest	Sandy Area	Total Transfer: Loss	Year:2005 Total
Water Bodies	54.32 (60.1)	0	21.77 (24.08)	10.54 (11.7)	0	3.68 (4.06)	0	0	0.06 (0.06)	36.05 (39.89)	90.37
Satluj River	1.67 (0.1)	911.46 (54.98)	67.22 (4.06)	267.56 (16.14)	0.11 (0.01)	1.21 (0.07)	0	0	408.44 (24.64)	746.21 (45.02)	1657.67
Vegetation	21.14 (1.2)	270.9 (15.39)	487.06 (27.67)	756.69 (43)	1.73 (0.1)	16.82 (0.96)	0	0.29 (0.02)	205.28 (11.66)	1272.85 (72.32)	1759.91
Agricultural Land	59.96 (0.06)	587.58 (0.63)	205.75 (0.22)	88584.96 (94.66)	93.8 (0.1)	3364.3 (3.6)	0	74.68 (0.08)	611.74 (0.65)	4997.81 (5.34)	93582.77
Wetland	1.44 (0.78)	0.62 (0.34)	0.12 (0.06)	109.96 (59.57)	60.02 (32.51)	12.15 (6.58)	0	0.17 (0.1)	0.12 (0.06)	124.58 (67.49)	184.6
Built Up	11.1 (0.28)	0.6 (0.02)	0.63 (0.02)	870.74 (22)	9.51 (0.24)	3063.27 (77.41)	0	0.75 (0.02)	0.46 (0.01)	893.79 (22.59)	3957.06
Barren Land	0.06 (0.16)	2.94 (7.87)	0	26.44 (70.85)	0	7.65 (20.5)	0	0	0.23 (0.62)	37.32 (100)	37.32
Forest	1.04 (0.07)	0.23 (0.02)	0	66.07 (4.98)	0	8.48 (0.64)	0	1250.09 (94.21)	1.03 (0.08)	76.85 (5.79)	1326.94
Sandy Area	0.23 (0.01)	801.01 (47.72)	110.47 (6.6)	318.4 (18.96)	0.33 (0.02)	18.14 (1.08)	0	0.23 (0.01)	429.65 (25.6)	1248.81 (74.4)	1678.46
Total Transfer: Gain	96.64 (64.01)	1663.84 (64.61)	405.96 (45.46)	2426.4 (2.67)	105.5 (63.73)	3432.44 (52.84)	0	76.12 (5.74)	1227.37 (74.07)	9434.27 (9.05)	
Year:2011 Total	150.96	2575.3	893.02	91011.36	165.5	6495.7	0	1326.21	1657.01		104275.1

Values are in hectares and parentheses values represent percentage.
Source: Data extracted from IRS P6 LISS III 2005 and IRS P6 LISS III 2011 Satellite Images.

Hundred percent transformation of barren land was observed. Its 71% share was distributed to agricultural land and 21% to built-up area and 8% to Satluj River. 74% transformation for other categories was recorded for sandy area.

Its 48% area went to Satluj River, 19% to agricultural land, 6.6% to vegetation, 1.1% to built-up area, 0.02% to wetland and 0.01% to water bodies and forest area. 72% vegetated area was transformed to other categories; calculated share distribution to various categories were 43% to agricultural land, 15.4% to Satluj River, 11.7% to sandy area, 1.2% to water

categories with 60% share shifted to agricultural land, 6.58% to built up area, 0.78% to water bodies, 0.34% to Satluj River, 0.1% to forest and 0.06% to vegetation and sandy area. Satluj River channel area gained 47.72% share of sandy area, 15.39% of vegetation, 7.87% of barren land, 0.63% of agriculture, 0.34% of wetland and 0.02% of built up area and forest area. Encroachment over other categories happened due to the increased water in Satluj River because of release of 50,000 cusecs of water from Bhakra Dam in Satluj River in 2011 (The Express Tribune, 2011).

Along with this addition, its 45% part was transferred to other categories. Sand carried by Satluj River was deposited in 24.64% of its channel path. 16.14% area earlier under Satluj River was used for agricultural purposes during this period. Its 4% area was transferred to vegetation cover, 0.1% to water bodies, 0.07% to built-up area and 0.01% to wetland (table 4 and figure 6). Area under water bodies was increased. This category was spread over about 1.2% of vegetation cover, 0.78% of wetland, 0.28% of built up area, 0.16% of barren land, 0.1% of Satluj River, 0.07% of forest, 0.06% of agricultural land and 0.01% of sandy area. Along with this gain, it confronts around 40% spatial loss for other categories. Its 24.08% share went to vegetation cover, 11.7% to agricultural land, 4.06% to built-up area and 0.06% to sandy area. In this period built up area was expanded. This expansion was contributed by barren land with 20.5% share transfer, wetland with 6.58%, water bodies with 4.06%, agricultural land with 3.6%, sandy area with 1.08%, forest with 0.64% and Satluj River with 0.07%. 23% area under built up category was changed and transferred to other categories. Its share distribution was 22% to agricultural area, 0.28% to water bodies, 0.24% to wetland, 0.02% to Satluj River, vegetation and forest area and 0.01% to sandy area. During these six years spatial pattern of agricultural land reflected inverse trend with comparison to previous time periods. Its spatial distribution was reduced and 5.34% area was transferred to other categories. 3.6% of its share was transferred to built up land, 0.65% to sandy area, 0.63% to Satluj River, 0.22% to vegetation, 0.1% to wetland, 0.08% to forest area and 0.06% to water bodies (table 4 and figure 6).

CONCLUSION

'Floodplain', a fragile segment on this earth, which is prone to two types of natural event i.e. gush of water in the form of flood and huge human population for fulfilling their ever increasing requirements through resource exploitation. Land use and land cover transformation analysis exhibits trends of change. It was 54.47% for 1975 to 1989 and for subsequent eleven years it was 12.72%, for 2000 to 2005 and 2005 to 2011 it reduced to 10.38% and 9.05% respectively.

Thus, from 1975 to 2011 collective 56.55% categorical transformation happened and consequent totally transformed and dominantly modified land cover categories incorporates barren land with 100% replacement, while wetland, vegetation, sandy area and water bodies are transformed with 99.56%, 98.25%, 85.6% and 80.13% respectively, which results into the positive spatial expansion of land use categories such as agricultural land and built up area, which was increased from 1975 to 2011 with 93.4% and 87.17% respectively at the cost of natural cover. Layout pattern extraction analysis for distinct temporal phases revealed that although human endeavor towards land transformation was moving in same direction but its magnitude varied with time, depending upon the channels of change. Analysis extracted from statistical figures revealed that every inch of available fertile part of this landscape was totally transformed for agricultural land at the cost of natural cover. Inherited natural physical features were disappeared from the Satluj floodplain frame with every passing interpreted temporal phase. These trends facilitate the smooth path for understanding the dynamic interactions and underlying mechanism between the mother earth and human. That may help in understanding the sustainability in a particular region and provide inputs for framing policies for sustainable development. It also shows the direction of changing human-environment interactions.

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