International Journal of Research in Social Sciences
Vol. 7 Issue 2, February 2017,
ISSN: 2249-2496 Impact Factor: 7.081
Journal Homepage: http://www.ijmra.us, Email: editorijmie@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

REGRESSION MODELING: A STATISTICAL APPROACH TO STUDY LAND USE AND LAND COVER CHANGE CAUSES

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Abstract

To discrete the descriptive monarchy of explanations statistical model approach has been initiated in land use and land cover studies. In that regression model is applied for identifying the causal relationship and prediction of change from the specific factors of land use and land cover change. Land use and land cover change a dynamic process proceeds with geological factors and progressive steps of human development. Punjab Satluj floodplain formed through river deposition action and later on attracted and habited by the human number that alters the surfacial use of this floodplain and resulted in expansion of human activities. Since mid twentieth century Punjab Satluj floodplain lost its 57% land cover. Locational characteristics of a floodplain played major role for this change. Here both natural and anthropogenic factors acted as important agent of change.

Causal links have been built and linked through statistical model. Regression model has been applied to explain the causal links and also predicts the possible change in dependent variable from the selected independent variables. Five links have been discussed that involved human population and agricultural expansion; human population and built up area expansion; human number and land use change; population density and land use change; land use and land cover change. Model approach proved suitable for explaining descriptive causal links with statistical base.

Keywords: Land use and Land cover Change; Satluj; Floodplain; Resource integration; Causal links; Regression Model.

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1. Introduction

A river is a natural attraction for settlement – be it agriculture, village or urban settlement; the Satluj River is no exception. Punjab Satluj floodplain stretched between 30°32' N to 31°35' N and 75°05' E to 76°44' E latitudes and longitudes respectively and cover 1042.751 Sq Kms area. The floodplain of this river offers immense scope for development. This process of development includes controlling the river through dams, river bandhs and barrages, which reduce the downstream flow of water. 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.

Further the natural wealth of the floodplain that includes flat surfaces with fertile soil, salubrious climate and ample water availability made this land suitable for agricultural expansion. This available land was subjected to tremendous land use and land cover change through a host of government policies, various Five Year Plans and Green Revolution package. Government initiatives promoted land use activities through Land Allocation Programmes and also Land Improvement Loan Act [1], consolidation of land holdings, wasteland reclamation, Minimum Support Price Scheme (1965), subsidies on agricultural inputs such as power, water and fertilizers, establishment of markets and promotion of agricultural research [2],[3],[4]. These efforts resulted in 57 percent land use and land cover transformations since mid twentieth century. Agricultural land expanded with 151% and built up area with 498% from 1950 to 2011 at the loss of land cover as barren land totally disappeared, water bodies lost 95%, vegetation 93%, wetland 88%, sandy area 87%, forest 46%, Satluj River 38% [5].

Statements have been generated from the causes of land use and land cover change for statistical modeling and for estimating the probability of further change through stated causal links. Regression model has been applied for this task due to its ability to explain the causal links with prediction of change.

2. Research Method

Two data sets have been prepared for explaining the causes of land use and land cover change (LULCC) and listed under descriptive inventory and statistical modeling.

Descriptive Inventory: Data set related with causes of land use and land cover change has been extracted from the secondary sources. Surface relief of Satluj floodplain area has been depicted through elevation and physiographic regions. Elevation data has been collected from the Survey of India Topographical sheets and physiographic regions has been extracted from the information provided by the Department of Soil and Water Conservation, Punjab. This department was also helpful for attaining the information of soil taxonomy and water depth. Surface water distribution was analyzed from the Survey of India Topographical Sheets. Climatic conditions were explained through temperature and precipitation and related data was collected from the Statistical Abstracts of Punjab.

Data base for anthropogenic causes of LULCC have been collected from Census of India, Statistical Abstract of Punjab and Survey of India (SOI) topographical sheets.

Statistical Modeling: Causal relationships were statistically analyzed with regression model. Karl Pearson correlation method was applied for understanding the vector of relationship and least square method was used to find the rate of dependency level. This process was done in SPSS software. Graphs were prepared in SPSS and Excel software.

3. Results and Analysis

Land use has been expanded at the cost of natural cover in Punjab Satluj floodplain. Total 57% land transformation has been observed since mid twentieth century. Natural and anthropogenic factors worked collaborately for land use and land cover change which has been explained through descriptive inventory and statistical modeling.

3.1. Descriptive Inventory

In this area *natural causes* of land use and land cover change involved plain terrain that ranged between 215 meters to 271.9 meters above mean sea level. This area has been characterized by

three types of plain i.e. piedmont plain, alluvial plain with sand dunes and active/recent floodplain. Due to inherent geomorphic property, this area is having a fertile layer of soil that renewed frequently with each flood.

This area has been characterized under four types of physiographic regions with fifteen types of soils. In Siwaliks, Typic Ustorthents soils have been found, which covered 1.06% area. In piedmont plain Udic Ustochrepts and Typic Ustochrepts type of soil found, which covered 3.02% area. Typic Ustochrepts found in piedmont plain area is slightly developed with fine loamy soil, which has been prone to moderate erosion. Alluvial plain has been attributed with Typic Ustipsamments, Typic Ustochrepts, Udic Ustochrepts, Fluventic Ustochrepts and Typic Haplustalfs varities of soil. Typic Ustipsamments and Typic Ustifluvents types of soil have been observed in Active/ Recent Floodplain area. Collectively, this area has been characterized with calcareous, sandy, coarse loamy, loamy to fine loamy type of soil, which reflects its fertility towards agronomic development on one side and on other side, it depicts the affect rate of surface water runoff and recharge capacity of ground water aquifer.

In floodplain area prominent natural resource is 'water'. During mid twentieth century spatial horizontal dimensions of this resource in the form of surface water covered 19210.49 hectare (18.42%) area. Vertically groundwater depth below surface level ranged between one meter to 12.33 meter during 1972.

On the climatic front , this area is attributed with warm temperate monsoon climate with dry winter. Average annual rainfall is ranged between 300 mm to 700 mm and mean annual temperature is 24.8° C.

This natural resource integration helped in the development of Agro-Ecological regions in this area. Study area covered under three Agro-Ecological zones i.e. western Himalayas sub humid eco region, northern plain dry sub humid eco region and northern plain semi arid eco region. All these natural factors encouraged *anthropogenic causes* of land use and land cover change that involved increase in human number and agricultural and built up area expansion. Process of increase in this human number was started with the rehabilitation of 1947 India-Pakistan

partition refugees. Government had allotted land to refugees and scheduled castes to this area [3]. This immigration adds number to already inhabited population. In 1961, population of this area was 2,00,753, which was increased to 21,98,128 in 2011. That increased number reflects increased population pressure on land, which was 161 persons/km² during 1961 and reached at 1763 persons/km² in 2011. Village level population density depicts similar trends with increased human pressure towards the centre of the study area. In 1961, 76.38 km² covered by 79 villages situated near to the Satluj River was uninhabited, but in 2011 number of villages accounted under this category was reduced to 6 and covered 1.98 km². This increasing human pressure started taking initiatives for exploiting the natural existed resources. They started channelizing and damming of river Satluj, so that flood risk can be reduced and further government plans, policies and implementation of Green revolution package stimulated the growth of agriculture sector in this area. Government initiatives and framed policies fueled this action. As this sector got increased expenditure under various Five Year Plans. 1,100.66 lakh rupees were sanctioned during Second Five Year Plan (1956-61), which was increased to 1,16,575.9 lakh rupees during Eleventh Five Year Plan (2007-2012). All these initiatives boost the agricultural expansion in this area, which covered 34.77 thousand hectares in 1955 and increased to 87.28 thousand hectares in 2011. This agricultural expansion attracts agro-based industries in this area, which further promote urban area expansion. That can be well explained through the spatial growth of Ludhiana town. With increased human number, their related demand for housing and infrastructure was also increased and resulted to the expanded built up area with five percent, which was covered 1,087.09 hectares in 1955 and elevated to 6,495.7 hectares in 2011 and that was well connected through transportation routes.

3.2. Statistical Modeling

Human increase, agricultural expansion and built up spread caused land use and land cover change in this area. Statements have been generated for statistical modeling from the causes discussed through descriptive inventory. Regression model has been applied to five statements i.e.

- *Human population and agricultural expansion;*
- *Human population and built up area expansion;*
- *Human number and land use change;*

- *Population density and land use change;*
- *Land use and land cover change*

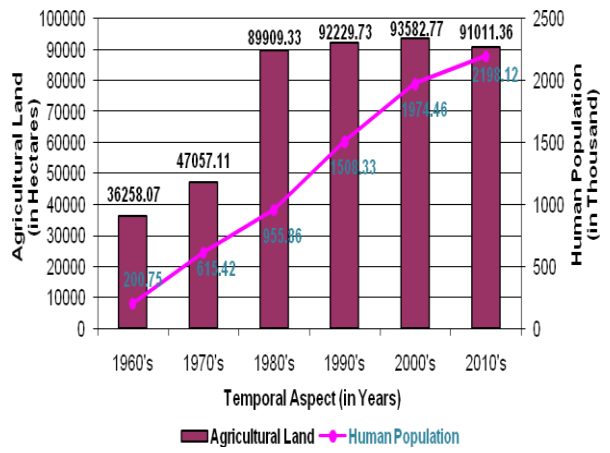
Human Population and Agricultural Expansion

Agricultural expansion and intensification is directly linked with the human increase. Statistically this statement has been proved with the application of correlation and regression techniques (figure 1 (a) & (b)). Land under agricultural use and human population was having strong positive relationship with 0.85 correlation coefficient value (figure 3.18). Dependency of agricultural expansion on human number was 72.4 percent (table 3.9). During 1960's area under agricultural use was 36258.07 hectares and human population was 200753. Agricultural area was increased to 47057.11 hectares for 1970's, where as human number reached at 615423. Area under agricultural land was increased by 42852.22 hectares in 1980's, 2320.4 hectares in 1990's, 1353.04 hectares in 2000's and decreased by 2571.41 hectares in 2010's. Human number was also added with 340443 in 1980's, 552472 in 1990's, 466125 in 2000's and 223665 in 2010's (figure 1 (a)).

Regression Equation: *Agricultural Land = 39.89+ 0.03 Human number*

Explanation of regression equation represents two situations. First is that, if there is no increase in human number then accounted land under agricultural use is 39.89 thousand hectares. Second situation states that if there is an increase in human number then land under agricultural use is expanded by 0.03 hectares (figure 1 (b)).

Population Increase and Agriculture Expansion: Relationship Description through Statistical Analysis



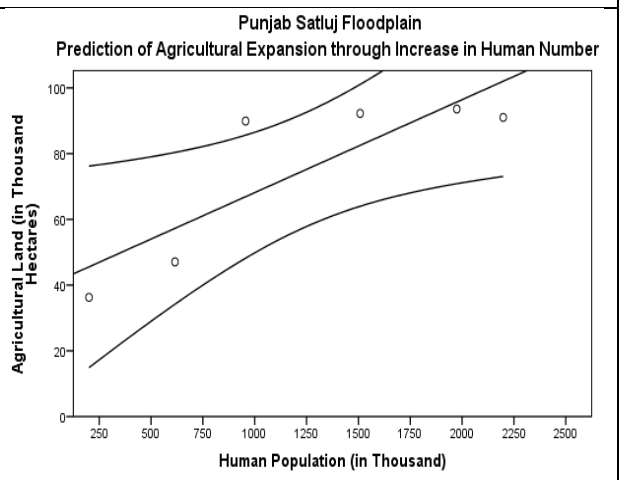


Figure: 1

a **b**

Discussed situations validate the statement, that population increase and agricultural expansion is directly related. Statistically applied model is significant as its calculated significant level is 0.032.

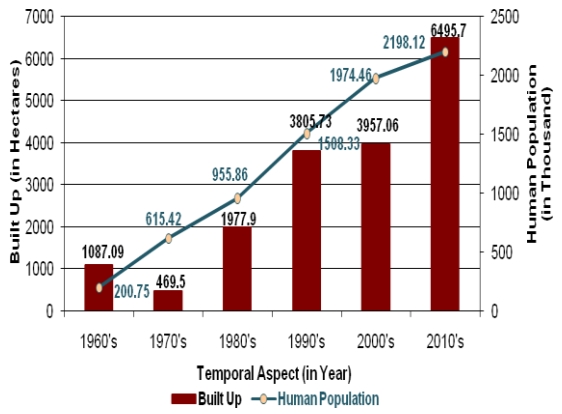
Human Population and Built up Area Expansion

Human population was increased with time. According to 1961 census, human existence was 200753 number that increased to 2198128 in 2010's. This increased number caused built up expansion. During 1960's, 1087.09 hectares of study area was under built up, which was accounted 469.5 hectares for 1970's, 1977.9 hectares for 1980's, 3805.73 hectares for 1990's, 3957.06 hectares for 2000's and 6495.7 hectares for 2010's (figure 2 (a)). Regression model has been applied for calculating the exact momentum of relationship between the population increases and built up area expansion. Both variables are having strong positive relationship with 0.93 correlation coefficient value (figure 2(b)). Estimated dependency rate of built up area on human population is 86.2 percent.

Regression Equation: *Built up area = -312.14 + 2.64 Human number*

This model predicts that if there is an addition of a human number then predicted built up expansion would be 2.64 hectares. These statements are significant as significant level of applied model is high with 0.008 calculated value. Mean prediction interval for linear regression is 95 percent and it is covered within the dotted curves of figure 2(b).

Population Increase and Built Up Expansion: Relationship Description through Statistical Analysis



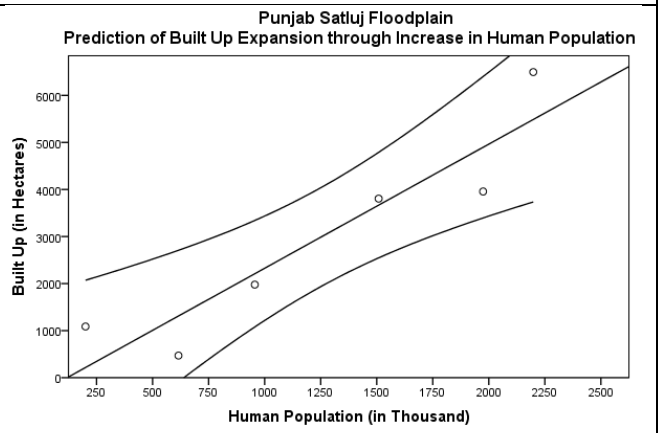
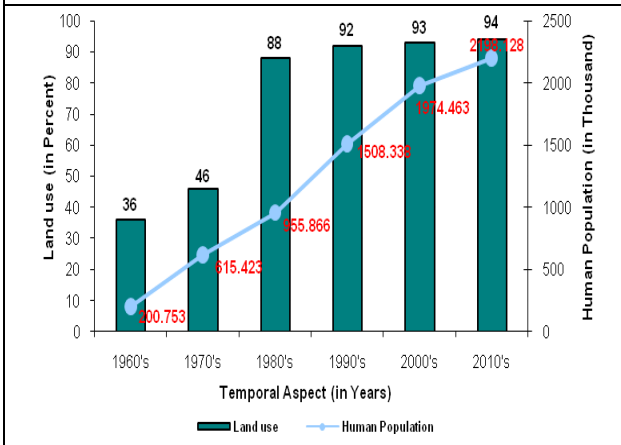


Figure: 2

a **b**

Human number and land use change: This study area experienced positive growth rate of population (figure 3(a)). This human number made changes in their occupied parcel of land with different land use activities and affects the land cover. Location of regression curve as reflected from figure 3(b) shows that there is a strong positive relationship between human number and land use with 0.87 correlation coefficient value. During 1960's, population was 200.75 thousand and area under land use category was 36 percent of the total study area.

Population Increase and Land use Change: Relationship Description through Statistical Analysis



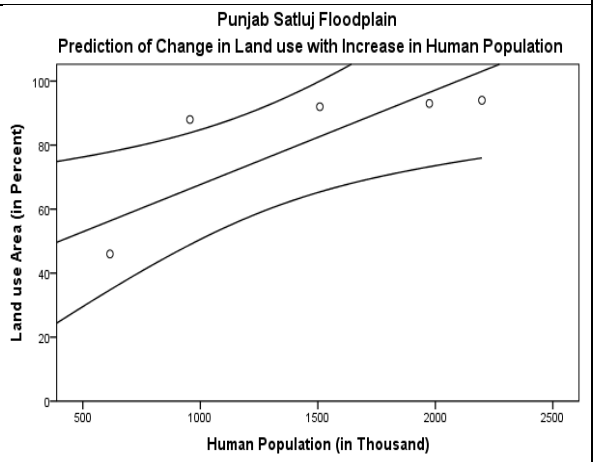


Figure: 3

a **b**

For 1970's, both variables increased, population number was reached at 615.42 thousand and land use was 46 percent of total study area. In 1980's, population number was 955.86 thousand and land use area was 88 percent. Population number increased to 15,08,338, 19,74,463 and 21,98,128 and land use expansion was reached at 92, 93 and 94 percent of study area for 1990's, 2000's and 2010's respectively (figure 3(a)).

This comparative change in both the variables depicts that there was 76.6 percent dependency between the dependent variable i.e. land use and independent variable or predictor i.e. human number.

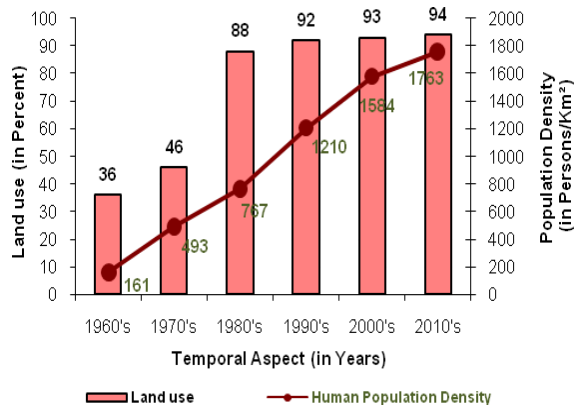
Regression Equation: *Land use= 38.16 + 0.03 Human number*

Graphical representation of regression line reflects that if there is no increase in human number then calculated land use covers 38.16 percent of study area, whereas addition of one number to existed population made 0.03 percent expansion of land use area (figure 3(b)).

Population density and land use change: Population density and land use change as reflected from figure 4 (a) & (b) was having a strong positive relationship with 0.87 correlation

coefficient. Interpretation of the visible relationship existed between both the variables (figure 4(b)) depicts that population density and area under land use was gradually increasing with time. During 1960's, population density was 161 person/km² and contribution of land use categories to total area was 36 percent. Both the variables experienced addition of values with time. For human density, calculated increase was 333 person/km² for 1970's, 273 person/km² for 1980's, 443 person/km² for 1990's, 374 person/km² for 2000's and 179 person/km² for 2010's. Spatial contribution of land use to study area was also increased with time, it was 10 percent for 1970's, 42 percent for 1980's, 4 percent for 1990's and one percent for 2000's and 2010's respectively. This changing pattern, when statistically analyzed provides the numerical value, which exhibits the level of dependency.

Population Density and Land use Change: Relationship Description through Statistical Analysis



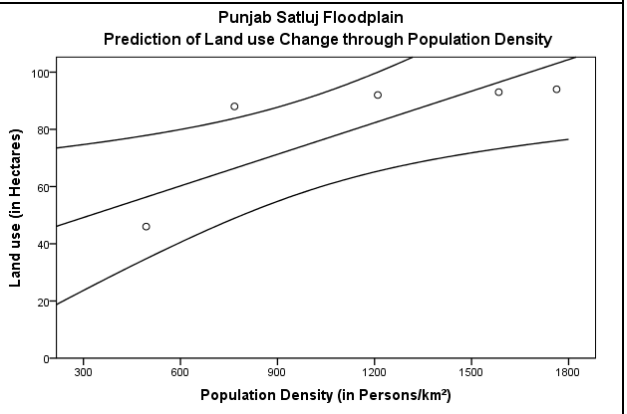


Figure: 4

a **b**

For this experiment, accounted level of dependency was 76.6 percent between the dependent variable (land use) and predictor (human density).

Regression Equation: *Land use= 38.15 + 0.037 Human density*

It has been calculated that if there is no change in human density, then area under land use would be 38.15 percent, whereas increase of one person/km² made 0.037 percent expansion to area

under land use (figure 4(b)). This statement was statistically significant as the calculated significant level for regression model is 0.02.

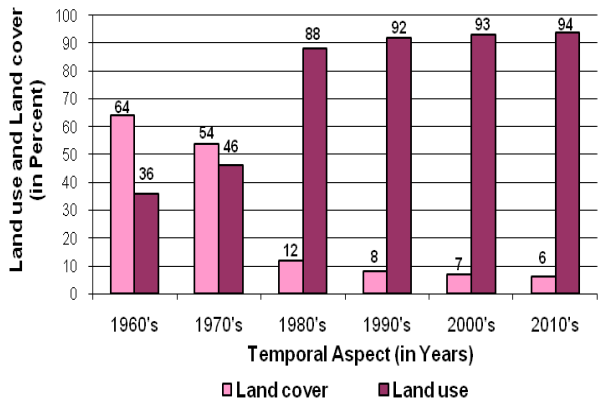
Land use and land cover change: This population pressure promotes the change in land cover through land use. With time this transformation of land cover for land use increased, these two variables were having perfect negative relationship (figure 5 (a) & (b)). Statistical analysis depicts that land use expansion inversely affects the land cover with -1 correlation coefficient. Change dependency of land cover on land use is 100 percent.

Regression Equation: *Land cover = 100 – 1 Land use*

Prediction of the change vector reveals that one percent expansion in land use initiates one percent reduction of the land cover area (figure 5(b)).

This proportional increment and reduction can be understood from figure 5(a); it shows the decadal impact of land use change on the land cover. During sixties natural cover was 64%, which was reduced by ten percent for the succeeding decade. This reduction rate was increased in eighties as land cover area contributed only 12% of study area during this span.

Land use Expansion and Land cover Reduction: Relationship Description through Statistical Analysis



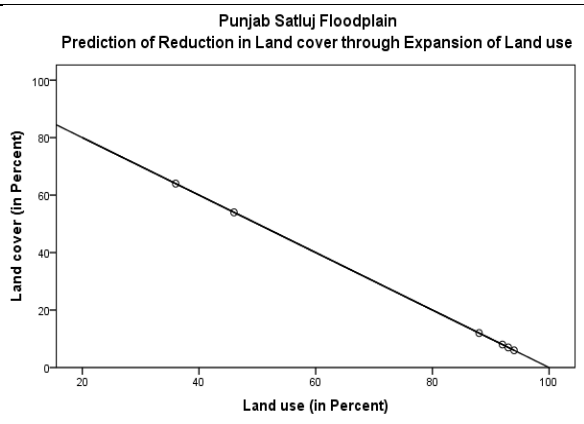


Figure: 5

a **b**

For the following years this decreasing trend was left with four percent reduction in land cover and for 2001 and 2011, this rate became constant at one percent and land cover area constitutes only six percent of the Satluj floodplain. Best fit regression line reflects the graphical location of the linear relationship exists between the land use and land cover and its downward slope shows the perfect negative correlation between the variables (figure 5(b)).

4. Conclusion

Since mid twentieth century more than half of the Punjab Satluj floodplain area faced land use and land cover transformations. Reasons of these huge transformations are human benefited or profited locational characteristics. Natural resource integration attracted human number to this area as Satluj floodplain area is attributed with the fertile alluvial soil, ample surface and sub surface water, flat terrain and monsoonal climate. These characteristics favour the origin of Agro-Ecological regions which promote agricultural expansion. Government initiatives through various policies, Five Year Plans and Green Revolution boost agricultural sector. These factors attract human population. With time human demands increased that resulted in agricultural and built up area expansion that consequently changed land cover. Probability of further change has been estimated through regression model that support the descriptive causal links of land use and land cover change in Punjab Satluj floodplain.

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