ISSN Print: 2394-7500
ISSN Online: 2394-5869
Impact Factor: 5.2
IJAR 2017; 3(7): 1084-1087
www.allresearchjournal.com
Received: 01-05-2017
Accepted: 02-06-2017

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Rural Infrastructure forecasting of Ganga basin and impact on food production and cropping pattern using multivariate regression analysis

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Abstract
The research involves a descriptive study of land use pattern of Ganga river basin and impact of population growth on it. The cropping pattern of 10 years have been analyzed using multivariate regression analysis. Due to increase in population there is an expected growth in the build-up area in the basin and an expected growth in cropping area. As a result of population growth there is a shift of cropping pattern from low yielding crops to high yielding crops. The study results shows that there is reduction in single crop area like Rabi and Kharif crop with increasing population. Results shows increase in Double and Triple crop cover in the basin with increase in population. The study clearly shows that with increase in population the cropping distribution changes and high yielding cropping practices are favored over the years. Results from the study can help in forecasting the cropping pattern against the expected population and the demand of fertilizers can be optimized by planning beforehand for the expected demand for specific type of cropping pattern.

Keywords: Infrastructure forecasting, multivariate regression analysis, land use pattern, Ganga river basin

1. Introduction

The Ganges basin is a part of the Ganges-Brahmaputra basin draining 1,086,000 square kilometers in Tibet, Nepal, India and Bangladesh. To the north, the Himalaya or lower parallel ranges beyond form the Ganges-Brahmaputra divide. On the west the Ganges Basin borders the Indus basin and then the Aravalli ridge. Southern limits are the Vindhyas and Chota Nagpur Plateau. On the east the Ganges merges with the Brahmaputra through a complex system of common distributaries into the Bay of Bengal. Its catchment lies in the states of Uttar Pradesh (294,364 km^2), Madhya Pradesh (198,962 km^2), Bihar (143,961 km^2), Rajasthan (112,490 km^2), West Bengal (71,485 km^2), Haryana (34,341 km^2), Himachal Pradesh (317 km^2) and Delhi (1,484 km^2), the whole of Bangladesh, Nepal and Bhutan. Several tributaries rise inside Tibet before flowing south through Nepal. The basin has a population of more than 500 million, making it the most populated river basin in the world.

The evolution of the Indian subcontinent through various geological time periods and the lithological, pedogenetic and climatic conditions prevailing during the commensurate time periods is an appropriate indicator of the present day soil characteristics in the region. Scientific study of soils commenced in India after the establishment of the Geological Survey of India in 1846. Preliminary pedological studies carried out in the 1840's and 1850's revealed that the soils found in the Indian subcontinent can be broadly grouped into four classes of Alluvial, Black soil, Red soil and Lateritic soils.

There is no alluvial basin in the world which can compare with the Ganga Basin in terms of size, fertility, acreage, and topography. It is the most densely populated river basin in the world and is often characterized as a granary or the bread basket of India. Agriculture or farming remains the mainstay of the people of this region. The crop profile includes subsistence crops such as cereals as well as cash crops such as sugarcane, oilseeds, pulses, tobacco, cotton etc. The irony of the situation does not reflect the agricultural wealth of the region. Most farmers are trapped in a vicious web of malnutrition, poverty, low productivity and poor health from which they desperately need to be rescued. The average farmer in the Ganga basin is a subsistence cultivator, who produces for his own needs and is left with very little surplus. The affluent farmers are in a minority and reap the benefits of mechanization, technology as well as expensive farm inputs. They have huge surpluses which can be traded in the markets. The difference, thus between the subsistence and the big farmer is defined by the degree of market participation and surplus production they generate. A study of the crop profiling or the cropping pattern indicate that physical factors such as soil conditions, topography as well as climatic criteria determined the distribution of crops. The green revolution and the legacy of modern technologies it has initiated in the field of agriculture have largely altered the traditional cropping pattern in the region. Irrigation facilities, chemical pesticides, fertilizers and improved seeds of a high yielding variety created through the application of genetic engineering are notable examples. Food crops such as cereals and pulses account for 75% of the acreage, non-food crops such as oilseeds, sugarcane, jute, cotton and others account for the rest.

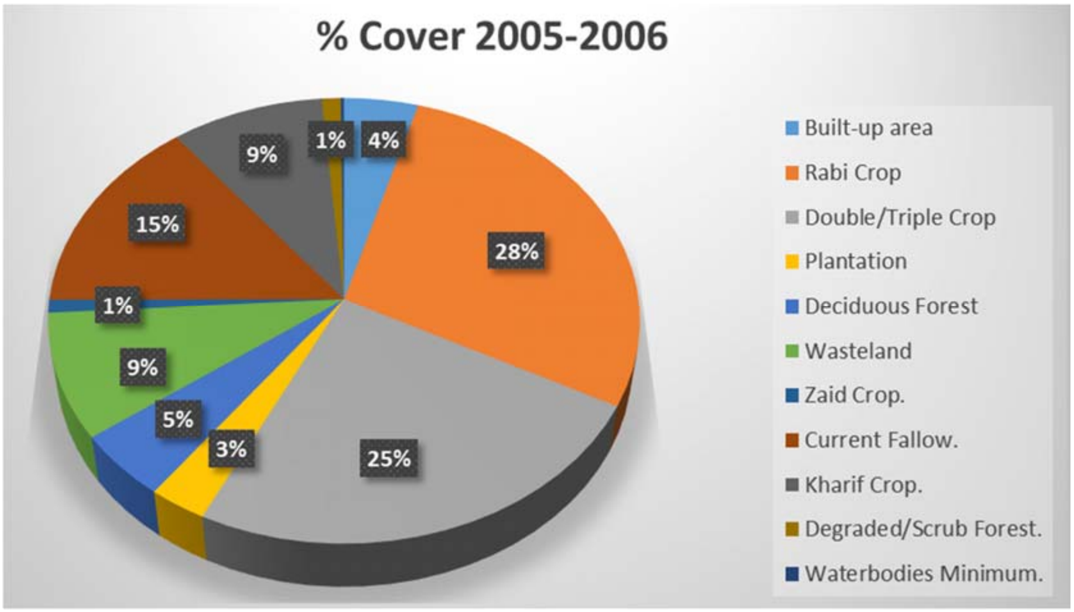

Fig 1: Land Cover of River Ganga Basin (2005-2006)

Land use is a description of how people utilize the land and socio-economic activity. At any one point or place, there may be multiple and alternate land uses, the specification of which may have a political dimension. Land cover is the physical material at the surface of the earth. Land covers include grass, asphalt, trees, bare ground, water, etc. This basin holds a variety of land cover and land use classes. The major part of basin is covered with agriculture accounting to 65.57%. The states falling under Ganga basin are extensively cultivated, constituting approximately about 40% of the total area of the India. Other major Land cover is Deciduous Forest accounting (16%) and statistics of level-I land use/land cover statistics of the Ganga basin.

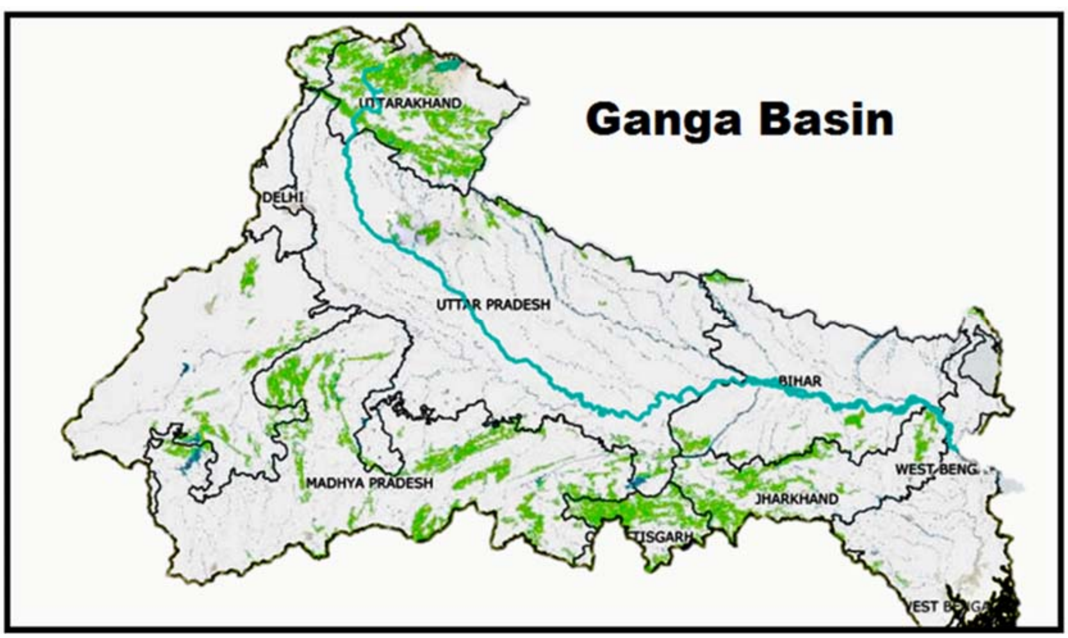

Fig 2: Ganga River Basin.

2. Methodology

In the study a statistical modeling called regression analysis is used. In this process the statistical process for estimating the relationships among variables is analyzed. It includes many techniques for modeling and analyzing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables (or 'predictors'). More specifically, regression analysis helps one understand how the typical value of the dependent variable (or 'criterion variable') changes when any one of the independent variables is varied, while the other independent variables are held fixed. Most commonly, regression analysis estimates the conditional expectation of the dependent variable given the independent variables – that is, the average value of the dependent variable when the independent variables are fixed. Less commonly, the focus is on a quantile, or other location parameter of the conditional distribution of the dependent variable given the independent variables. In all cases, the estimation target is a function of the independent variables called the regression function. In regression analysis, it is also of interest to characterize the variation of the dependent variable around the regression function which can be described by a probability distribution. A related but distinct approach is necessary condition analysis (NCA), which estimates the maximum (rather than average) value of the dependent variable for a given value of the independent variable (ceiling line rather than central line) in order to identify what value of the independent variable is necessary but not sufficient for a given value of the dependent variable. Regression analysis is widely used for prediction and forecasting, where its use has substantial overlap with the field of machine learning. Regression analysis is also used to understand which among the independent variables are related to the dependent variable, and to explore the forms of these relationships. In restricted circumstances, regression analysis can be used to infer causal relationships between the independent and dependent variables. However this can lead to illusions or false relationships, so caution is advisable; for example, correlation does not imply causation.

The following formulations is used for the calculations of the coefficient sand residues of the regression model:

$$Y_i = \alpha + \beta_1 X_{i,1} + \cdots + \beta_p X_{i,p} + \varepsilon_i \quad \text{Eq.1}$$

$$Y_i = E(Y|X_i) + \epsilon_i \quad \text{Eq. 2}$$

$$\hat{\sigma} = \sqrt{\textstyle\sum_i r_i^2 / (n - p - 1)} \quad \text{Eq. 3}$$

3. Regression Models

The models obtained are in the form of a linear variable equation. The independent parameter is taken as the population of the whole basin. Due to cyclic data for the population, linearly varying population is considered for the area.

3.1 Infrastructure Development Model

As hypothesized in the beginning of the study an expected increment in build-up area is observed with >75% R-squared value. Increase in build-up area represents increase in the infrastructure development over the 10 year of the study period. The constant value is small and negative representing slightly nonlinear relation for the present time scale.

Build up Area (L ha) = - 11.6 + 0.0116 Population (La); R^2 = 79.6%

3.2 High Yield Cropping Model

Second hypothesis for the study also shows positive results in terms of the sight in cropping pattern towards high yield crops. Population growth resulted in increased in demand and farmers have adopted double and triple coping pattern to meet the demand. The regression constant is extremely high and negative indication the unreliability of the model for long time scale. However the high R-squared value makes this model reliable for short term planning.

Double/Triple Crop (L ha) = - 345 + 0.229 Population (La); R^2 = 85.5%
Current Fallow (L ha) = 190 - 0.0880 Population (La); R^2 = 92.4%

3.3 Single Yield Cropping Model

This model again justifies the shift in cropping pattern from single crop to double cropping style. <75% R-squared value shows negative correlation between the increasing population and single crops.

Rabi (L ha) = 235 - 0.0997 Population (La); R^2 = 64.7%
Karif Crop (L ha) = 59.8 - 0.0215 Population (La); R^2 = 49.6%
Zaid Crop (L ha) = 14.5 - 0.00677 Population (La); R^2 = 63.2%

3.4 Land Exploitation Model

As a result of the increased in demand for the infrastructure and grains, there are strong evidence for increase in land exploitation in the basin with increase in population. The R-squared value is extremely high with a relatively low and positive regression constant.
Waste Land (L ha) = 65.9 - 0.0245 Population (La); R2 = 91.5%

4. Results and Discussions

The results are in the favor of the hypothesis regarding the shift in cropping pattern from single crop towards the double crops. The cropping pattern have increased in terms of the land cover area. Double cropping pattern have increased to 58% in 2014-2015 from 25% in the year of 2005-2006. As double crops helps in growing two or more than two crops at the same time, high demand can be managed more efficiently. This high demand can be correlated to increase in infrastructure demand by other studies. The build-up area can be considered a goof indicator of the infrastructure development and is found out to be in a positive correlation with increasing population. Rabi crop practice has taken a down fall from 28% in 2005 to 12% in 2014.

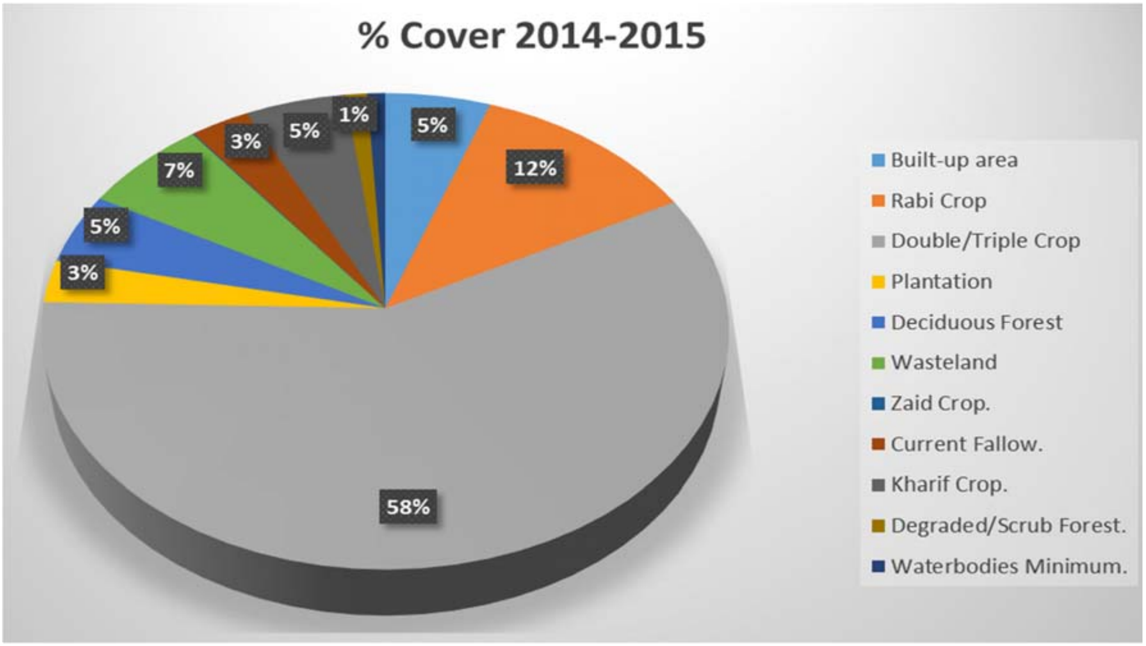

Fig 3: Land Use cove of Ganga Basin (2014-2015)

From the results future land use pattern can be forecasted for short coming years. For the infrastructure demand, the indicator of "Build-Up Area" can be used. For the demand of the food production and fertilizers, the indicator of "Double Crop" can be used over Single crop of Rabi and Karif.

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