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Case Study

An Empirical Analysis of Forest Transition and Drivers Contributing to Forest Cover Change – A Case Study of Jharkhand State

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A B S T R A C T

The present study entitled "An empirical analysis of Forest transition and the drivers contributing to forest cover change – A case study of Jharkhand state" was conducted for the period of 2000 to 2015. The aim of this study was to develop an empirical model for forest cover change and to identify drivers contributing to forest cover change. Stepwise multiple regression models were applied to find the significant drivers of forest cover. The results revealed that the livestock population particularly cattle population and fallow land under the land use classification are the significant drivers to the weighted forest cover change at 5 per cent level of significance leading to occurrence of forest transition in the state. The overall model was significant (p = 0.000) at 5 per cent level of significance with the value of adjusted R^2 as 0.83. In the current study, cattle population (driver) has been found to be directly related with forest transition in Jharkhand. The study recommends implementation of mixed farming practices in the state of Jharkhand for the positive forest transition.

Keywords

Forest transition, Forest cover, Livestock, Regression models, Mixed farming

Introduction

The concept and theory of forest transition (FT) was introduced by A. S. Mather in the early 1990s (Mather, 1990, 1992; Mather and Needle, 1998). Mather and Needle (1998) discussed that area of forests in many developed economies is increasing after periods of decline. FT is the decline of forest cover followed by the recovery over a time period. In the beginning, during the process of FT, forest cover declines in periods of massive population growth, which is linked with the growing food demand and the placement of settlements. After reaching a leverage point i.e. a place within the system where a small shift can produce big changes (Meadows, 1999) this trend gets reversed (Barbier *et al.*, 2010). In the first phase of development, forests are abundant and a major phase of deforestation takes place. The turning point occurs when the phase of stagnation appears and finally a phase of reforestation takes place. The turning point when deforestation (decline of forest cover) stopped and reforestation (recovery in forest cover) commences is known as the point of inflection in the FT (Rudel *et al.*, 2011). Broadly, FT is used to describe the pattern of forests and the transformations of urbanization and industrialization.

The process was first described for Europe, later for North America and eventually also

for countries outside those two regions (Mather, 1992; Mather and Needle, 1998; Rudel *et al.,* 2005; Walker, 1993). Some of the countries have experienced the FT in early 1800 centuries, some in 1900 century and few very recently.

Mather undertook a comparative historical study of forest cover change in four western and northern European societies (Mather *et al.,* 1998, 1999; Mather and Fairbairn, 2000). Many European countries, such as France, Hungary, Denmark (Knudsen, 1987), The Netherlands (Grandjean, 1987), Scotland (Walker and Kirby, 1989), Bulgaria (FAO, 1988), Iceland (Blondal, 1987) and Switzerland (de Saussay, 1987), forest expansion have occurred but with different rates and magnitudes. Based on these studies Scientists have linked FT to economic development, industrialization and urbanization at sub-national scales (Meyfroidt, 2013) and at multinational scales e.g. (Rudel *et al.,* 2005; Mather, 2007).

Besides European countries, forest transition have also occurred in Asia where the net loss of forest has now been halted and is replaced by a net increase in forest cover (Mather, 2007; Meyfroidt and Lambin, 2011; Southworth *et al.,* 2010). Meanwhile, India's forest area began to increase since about the 1980s, when the country had a forest cover of 19 percent, after declining continuously for about seven decades since the year 1900 to early 1970s (Singh *et al.,* 2017; Bhojvaid *et al.,* 2016). A progressive forest cover increase has been confirmed since then, by comparing data for the years 1990, 2000 and 2005 reported in FAO(2006) (Southworth *et al.,* 2010).

Historical studies of forest cover reveals that the British period in India was not favorable for our country. Maximum destruction and deforestation was caused during the two subsequent world wars when India was forced to fulfill the demands of woods and timber during that period. Forest products and timber was supplied from India to England at a very heavy rate and this led to plummeted forest area of the country (Bhojvaid *et al.,* 2016). However, the silver lining came after independence of India with the legal policy framework (Bhojvaid *et al.,* 2016). Causes and factors that reduced deforestation and forest degradation and resulted in forest recovery, includes agricultural intensification, government policies, private tree and forest production and smallholder and community forestry (Singh *et al.,* 2017).

A similar trend of forest transition is seen in Jharkhand by studying different drivers, as discussed late, related to the state. The land use pattern in Jharkhand has a large area under forest cover (around 29 percent). Moreover, forest cover of Jharkhand has shown a positive growth in recent years. At the same time, the performance of Jharkhand economy, for last few years, has been better than the national average. In the last ten years agricultural production has more than doubled in Jharkhand and there has been a consistent increase in the population of cattle, buffalo and sheep during a decade.

After reviewing the literature, it was realized that limited literature exists on empirical evaluation and analytical framework on forest transition at national and particularly at regional or local level with the application of statistical techniques. The following objectives are being considered for the study of Jharkhand.

Development of an empirical model for forest cover change using classical empirical models;

Identify drivers contributing to forest cover change or FT.

Materials and Methods

Study area

The present investigation was conducted on Jharkhand (Fig. 1) which is one of the most prolific mineral producing states of the country. It lies between 22° 00' N to 24° 37' N latitude and 83° 15' E to 87° 01' E longitude. The geographical area of the state is 79,714 Km^2 which accounts 2.42 percent of the country's geographical area. It occupies about 29 percent of the area of the state under forests and woodlands. The total population of the state is 32.97 million, which is 2.27 percent of India's population. According to Census 2011, the proportion of male and female is 52 and 48 percent respectively. However, the rural population is 75.95 percent, whereas urban population 24.05 percent along with tribal population 26.21 percent. Most of the parts of state lie on the Chotanagpur plateau, which forms the source of some important rivers flowing in the state such as Koel, Damodar, Brahmani, Kharkai, and Subarnarekha.

The state has forest area as 23,605 Km^2, however the forest cover is 22,930 Km^2, of which the average very dense forest is approximately 11 percent, average medium dense forest is 42 percent, while the average open forest is 46 percent over the last fifteen years. Among the nine fold classification of land use, total average cultivable land in Jharkhand is 28,820 Km^2. The cultivable land includes net area sown and current fallow land. As has been noted, out of the total land in Jharkhand around 17 percent is the average net sown area, 31 percent is average fallow land and 4 percent is average cultivable waste land in the last fifteen years. Correspondingly, the average area of land which is not available for cultivation is 13, 233 Km^2 with average area of land being used under Permanent Pastures & other Grazing Land is 1, 111 in Km^2. In the last fifteen years (2000-2015) agricultural production has more than doubled in Jharkhand. In fact, the total food grain production has increased from 2,011 thousand tones to around 4,735 thousand tones, within a decade, but at the same time there is just a marginal increase in productivity of food grains within the same period. On the whole, the average productivity of Jharkhand soil is 2,858 Kg per hectare where maximum productivity of *rabi* crop is 1,330.28 kg per hectare and maximum *kharif* production is around 1,967 kg per hectare. Furthermore, the performance of Jharkhand, for last few years, has been better than the national average. By and large, the Gross State Domestic Product of the state is projected to increase by 8.83 percent and the Net State Domestic Product (NSDP) by 8.9 percent in this financial year (2015-16). Likewise, the per capita income of the state at constant prices was 18,510 rupees in 2004-05 and is projected to be Rs. 33,260 in 2015-16. Moreover, the average contribution of primary sector to the state GDP is around 22,892 crores also 24,514 crores and 34,767 crores from secondary and tertiary sectors, respectively. In essence, the population of livestock has shown consistent increase in the last fifteen years having average population of cattle as 84, 66,555 with maximum of 15, 05,544 buffalo and minimum of 4, 76,336 sheep in the state.

Data collection

Data availability and reliability are the key constraints in the analysis of FTs worldwide (Mather, 2000). Therefore, the availability of continuous data was hurdle in completion of this thesis. The secondary data was collected from 2001 to 2015 from central and state government annual, biannual reports of forest department, agriculture department, directorate of economic and statistics,

government official websites and various other state reports published time to time. This duration of data collection was selected because this state was separated from Bihar in 2000. There were some data gaps, which were estimated using interpolation method. Growth rate was used for missing values in livestock population. The data were analyzed by applying basic and advanced statistical techniques like descriptive statistics, correlation, linear and non-linear multiple regression models.

Parameters used

The forest cover is the most important parameters used for the study of forest transition. The key potential parameters responsible for the forest cover change are classes of land use pattern, state Gross State Domestic Product and Net State Domestic Product, share of primary, secondary and tertiary sectors, agricultural production and productivity and livestock population. Table 1 shows all the parameters used in this study with their symbols, its unit and their source of collection.

Descriptive statistics

Correlation

Correlation coefficient is a method to establish the magnitude and direction of linear relationship between two or more variables. Prof. Karl Pearson, gave a measure of correlation between two variables known as Karl Pearson's Correlation coefficient as given below, which ranges from -1 and +1, if $r = +1$ then it is perfect positive correlation; if $r = -1$ then it is a perfect negative correlation.

$$r_{xy} = \frac{Cov(X,Y)}{\sqrt{V(X)V(Y)}}$$

Where X and Y are two variables, Cov (X, Y) is the covariance between X and Y and V(X) and V(Y) are the variance of X and Y respectively.

Regression Analysis

Regression analysis is a statistical device used for estimation or prediction of unknown values of one variable from known values of one or more than one variables. The variable which is used to predict the variable of interest is known as independent (X) or explanatory variable and the variable which is predicted is known as dependent (Y) or explained variable. Multiple Regressions allows additional factors to enter the analysis separately so that the effect of each can be estimated. It is valuable for quantifying the impact of various simultaneous influences upon a single dependent variable.

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 \ldots\ldots\ldots\ldots\ldots\ldots b_nX_n$$

Where,

$Y =$ Dependent or explained variable

$X_i =$ Independent or explanatory variable

$a =$ Intercept

$b_i =$ Constant's

Stepwise Regression Model

Stepwise regression drops variables from the model if they lose their significance as other variables are added. The variables added, having the smallest P-value, considered most significant and is forwarded at each step and simultaneously after entering the new variable, any variables that no longer make significant partial contributions are dropped

from the model at each step. A variable entered into the model at some stage may eventually be eliminated because of its overlap with variables entered at later stages. At each stage, each variable in the model makes a significant contribution, so no variables are dropped.

Interpolation

Interpolation is the process of finding unknown values from known values. Interpolation is one of the simplest methods which require knowledge of two point's constant rate of change. Interpolation is the problem of fitting a smooth curve through a given set of points, which is useful in data analysis and in numerical analysis. The Lagrange's interpolation polynomial is the interpolation technique published by Lagrange in 1795 (Jeffreys and Jeffreys 1988). The Lagrange interpolating polynomial (Issacson and Keller, 1996; Burden and Faires, 2005) is the polynomial of degree n that passes through $(n+1)$ points $(n_i + 1_i)$;

$i = 0, 1, 2, \ldots, n$. Let

$$P(x) = \sum_{j=0}^{n} P_j(x)$$

Where,

$$P_j(x) = y_j \prod_{k=0, k \neq j}^{n} \frac{x - x_k}{x_j - x_k}$$

The function $P(x)$ passes through the point $(n_i + 1_i)$ i.e. $P(x_i) = y_i$

This method was used to find the missing data of forest cover along with the different density class of FC like very dense forest, moderately dense forest and open forest.

Newton's forward method is another interpolation method and is used to interpolate the values of y near the beginning of a set of tabular values. If $y = f(x)$ for any given value of x when a set $\{x_0, y_0\}, \{x_1, y_1\} \ldots\ldots\ldots\ldots \{x_n, y_n\}$ are given, then:

$$y_p = y_0 + p * \delta_1 + \frac{p(p-1)}{2} * \delta_2 + \frac{p(p-1)(p-2)}{3!} * \delta_3 \ldots\ldots\ldots\ldots$$

$$p = \frac{(x - x_0)}{h}$$

Weighted forest cover

Weighted forest cover is calculated by multiplying the forest area with its weight. The weights (W) for respective density classes were estimated through defined methodologies. The weight for different density classes were assigned to rationalize and achieving uniformity among the different density classes.

Forest cover index is calculated as

$$Forest\ Cover\ Index = W_V \times A_V + W_M \times A_M + W_O \times A_O + W_S \times A_S$$

Where:

W_V = weight assigned to very dense forest

W_M = weight assigned to moderately dense forest

W_O = weight assigned to open forest

W_S = weight assigned to scrub

A_V = area of very dense forest

A_M = area of moderately dense forest

A_O = area of open forest

A_S = area of scrub

W = Ratio of average of each density class and sum of average of all class.

Results and Discussion

The given Table 2. focuses on the descriptive statistics about the explanatory drivers, which is directly or indirectly influencing the forest cover of the state and discusses the results based on appropriate statistical analysis.

Distribution of forest cover and its density class

The forest cover of Jharkhand is 23,478 Km^2 (SFR, 2015), which constitutes 29 percent of state's geographical area. The area covered under very dense forest is 2,588 Km^2 which has been increased by 44 km^2 from previous assessment of 2003. Positive increase in open forest and scrub area was also observed during the period.

Table 3, shows the total area under forest cover and density class since 2001 to 2015 as per FSI reports. Change in forest cover in different time periods under different density classes is reported in Table 4.

Little change was noticed in very dense forest throughout the period assessment i.e. 2003 to 2015; whereas the area under open forest has shown relatively more changes during the period. The increase in forest cover is attributed to the plantation and protection measures implemented by the state (SFR, 2015).

Weighted Forest Cover (WFC)

Weighted forest cover is calculated by multiplying the forest area with its weight. The weights for respective density classes were estimated through defined methodologies. The weight for different density classes were assigned to rationalize and achieving uniformity among the different density classes.

The cluster of different associated parameters may also provide an explanation of forest transition in the form of forest cover change over the last fifteen years. Forest cover change is the resultant of direct as well as indirect causes which has a multiple and complex relationship with the forest cover. The below graphs is an attempt to see the changes in forest cover with the associated parameter. It is evident from the graphs that the change in forest cover has multiple and complex relationship with parameters like fallow land, agricultural production and productivity, livestock population, state gross domestic product and state GDP per capita and share of primary sector in state GDP. The graph.1 explains the association of forest cover with the parameters related to agricultural sector. The increase in agricultural production as well as productivity of the state was consistent except in the years 2005 and 2010, there was slight decrease. Increase in agriculture production provides an opportunity for the employment.

The graph 2 reveals that the livestock population particularly cattle population increased consistently, however the decline in trend was very marginal in last few years. Cultivation of livestock is an important livelihood opportunity particularly for rural community and it does reflect land use intensification. It involves the collection of fodder from forests and agricultural fields,

and grazing in the forests lands. However due to expansion of agricultural sector, the dependency of livestock on the forest has been reduced significantly, which ultimately facilitating forest transition.

Though, the relationship between the livestock demand and forest contribution to rural livelihoods within a wider context of economic development can be considered to favor forest transition.

The states gross domestic product as well as the per capita GDP of the state has high significance in the changes in forest cover as evident from the graph 3. The contribution of primary sector in state GDP in the form of primarily agriculture that can be measured by the *percent share of agriculture in a country's GDP* has significant impact on the forest transition. This variable also signifies the contribution of farm mechanization and technological inputs into agricultural production. Higher share of agriculture to GDP implies better employment opportunities for rural households. This may concur with agricultural intensification, and subsequently a lower pressure on the forests and thus a moving forward towards FT.

Regression analysis

Stepwise multiple regression models were applied to find the significant drivers of forest cover. After applying the stepwise option, the cattle population and the fallow land, under the land use classification are the two drivers that came out to be significant at 5 per cent level of significance. The overall model was significant (p = 0.000) and showed that the cattle population and the fallow land has significant impact in the change in the weighted forest cover. The other associated drivers which didn't come out be significant may have some indirect relationship with weighted forest cover. The relationship between these non significant drivers may have some other complex relationship with that of weighted forest cover. The F value is 34.81 (p = 0.000) with the standard error of estimates is 38.52. The adjusted R^2 of the model was 0.83, means the 83 per cent of the variability of the weighted forest cover is explained by the drivers' cattle and fallow land.

Model for weighted forest cover is explained as

$$WFC = 4181.96 + 0.00014 * Cattle + 0.007 * Fallow\ Land$$

More than half of the land under the land use classification is used for agriculture (GoI, 2013). This includes 140.02 million ha net sown area under cultivation and 26.17 million ha for non-agricultural uses (GoI, 2013). In India, the agriculture sector is predominantly of mixed crop-livestock farming system, where the livestock particularly cattle provides alternate source of income to the farmers. The development of livestock sector is more inclusive and can result in a sustainable agriculture system (GoI, 2014). The growth rate of livestock population in the Jharkhand was high and has consistently grown till 2008, but there was slight decrease the population growth thereafter.

The forests of the state face various pressures of illicit felling for domestic as well as commercial purposes, forest fires, cultivation for agriculture, etc (GoI, 2010). The reason of heavy pressure on forests is due to growth livestock population. However, with continuous and consistent increase in agricultural production and productivity over the last one and half decade, the deforestation declined continuously, which ultimately reduced the pressure from the forests particularly for the feeds of livestock and became an alternate source of food for livestock in the state.

Table.1 Description of parameters of forest cover change

Symbol	Parameter	Unit of measurement	Source of data
FC	Forest cover	Km^2	State of Forest Report, FSI, Dehradun(2001 to 2015)
FA	Forest area	Km^2	State of Forest Report, FSI, Dehradun(2001 to 2015)
VDF	Very dense forest	Km^2	State of Forest Report, FSI, Dehradun(2001 to 2015)
MDF	Moderately dense forest	Km^2	State of Forest Report, FSI, Dehradun(2001 to 2015)
OF	Open forest	Km^2	State of Forest Report, FSI, Dehradun(2001 to 2015)
S	Scrub	Km^2	State of Forest Report, FSI, Dehradun(2001 to 2015)
GA	Geographical area	Km^2	State of Forest Report, FSI, Dehradun(2001 to 2015)
NAG	Land put to non - agriculture use	Km^2	Directorate of Economics and Statistics, Department of Agriculture and Cooperation.
UC	Barren and unculturable land	Km^2	Directorate of Economics and Statistics, Department of Agriculture and Cooperation.
PG	Permanent Pastures & other Grazing Land	Km^2	Directorate of Economics and Statistics, Department of Agriculture and Cooperation.
TC	Miscellaneous Tree crop &Groves (not included in net area sown)	Km^2	Directorate of Economics and Statistics, Department of Agriculture and Cooperation.
CW	Culturable Waste land	Km^2	Directorate of Economics and Statistics, Department of Agriculture and Cooperation.
FL	Fallow land, other than current fallows	Km^2	Directorate of Economics and Statistics, Department of Agriculture and Cooperation.
CF	Current fallows	Km^2	Directorate of Economics and Statistics, Department of Agriculture and Cooperation.
NAS	Net Area Sown	Km^2	Directorate of Economics and Statistics, Department of Agriculture and Cooperation.
GSDP	Gross state domestic product at constant prices	Crores	Jharkhand Economic Survey Report, 2015-16
NSDP	Net state domestic product at constant prices	Crores	Jharkhand Economic Survey Report, 2015-16
PNSDP	Per Capita Net State Domestic Product at Constant Prices	Crores	Jharkhand Economic Survey Report, 2015-16
KH	Kharif crop	Yield/hectare	Directorate of Economics and Statistics, Department of Agriculture and Cooperation.
RB	Rabi crop	Yield/hectare	Directorate of Economics and Statistics, Department of Agriculture and Cooperation.
Total	Food grain productivity	Yield/hectare	Directorate of Economics and Statistics, Department of Agriculture and Cooperation.

PS	Primary sector	Crores	Jharkhand Economic Survey Report, 2015-16
SS	Secondary Sector	Crores	Jharkhand Economic Survey Report, 2015-16
TS	Tertiary Sector	Crores	Jharkhand Economic Survey Report, 2015-16
CT	Total population of cattle in Jharkhand	Numbers	Livestock Census. All India Report, Ministry of Agriculture Department of Animal Husbandry, Dairying and Fisheries, New Delhi, Government of India.
BF	Total population of buffalo in Jharkhand	Numbers	Livestock Census. All India Report, Ministry of Agriculture Department of Animal Husbandry, Dairying and Fisheries, New Delhi, Government of India.
SH	Total population of sheep in Jharkhand	Numbers	Livestock Census. All India Report, Ministry of Agriculture Department of Animal Husbandry, Dairying and Fisheries, New Delhi, Government of India.
CG	Cattle growth	Percent	Livestock Census. All India Report, Ministry of Agriculture Department of Animal Husbandry, Dairying and Fisheries, New Delhi, Government of India.
BG	Buffalo growth	Percent	Livestock Census. All India Report, Ministry of Agriculture Department of Animal Husbandry, Dairying and Fisheries, New Delhi, Government of India.
SG	Sheep growth	Percent	Livestock Census. All India Report, Ministry of Agriculture Department of Animal Husbandry, Dairying and Fisheries, New Delhi, Government of India.
TF	Total food grain production	Thousand tones	Directorate of Economics and Statistics, Department of Agriculture and Cooperation.

Table.2 Descriptive statistic of the explanatory drivers

Parameter	Mean ± S.E	Max	Min
Forest Cover	22930.88 ± 86.10	23478.00	22591.00
Very Dense Forest	2574.93 ± 7.92	2595.00	2496.00
Moderately Dense Forest	9670.19 ± 82.57	9941.50	8939.31
Open Forest	10676.92 ± 101.81	11227.00	10196.56
Scrub	713.75 ± 21.19	976.00	670.00
Land put to non agriculture use	7571.22 ± 36.97	7753.30	7095.48
Barren and unculturable land	5662.71 ±6. 66	5718.78	5636.48
Permanent Pastures & other Grazing Land	1111.67 ± 7.78	1207.62	1096.90
Miscellaneous Tree crop &Groves (not included in net area sown)	912.61 ± 16.59	1019.85	830.00
Culturable Waste land	3365.84 ± 11.94	3492.36	3326.71
Fallow land, other than current fallows	9861.23 ± 146.80	10465.61	9011.37
Current fallows	14884.85 ± 232.35	17288.52	13936.98
Net Area Sown	13936.24 ± 373.17	15654.75	10853.66
Gross state domestic product at constant prices	82173.75 ± 6011.51	129225.00	57848.00
Net state domestic product at constant prices	71154.75 ± 5070.01	111295.00	50678.00
Per Capita Net State Domestic Product at Constant Prices	23482.65 ± 1255.86	33260.00	17406.00
Kharif crop	1527.78 ± 83.29	1967.00	1037.00
Rabi crop	1330.28 ± 41.24	1560.00	1016.00
Food grain productivity	2858.00 ± 99.93	3481.00	2093.00
Total food grain production	3150.15 ± 288.54	4734.90	1876.60
Primary sector	22892.20 ± 1905.03	37288.94	15440.15
Secondary Sector	24514.03 ± 787.78	29109.62	19411.21
Tertiary Sector	34767.62 ± 3515.99	62827.30	19679.21
Total population of cattle	8466555.12 ± 105572.29	8781067.00	7659000.00
Total population of buffalo	1369027.4 ± 22193.01	1505544.00	1185942.00
Total population of sheep	559228.7 ± 14915.64	680000.00	476336.0

Table.3 Distribution of forest density of Jharkhand (in Km^2)

Year	FC	VDF	MDF	OF	S
2001	22637	11787		10850	976
2003	22716	2544	9137	11035	733
2005	22591	2544	9078	10969	676
2007	22894	2590	9899	10405	683
2011	22977	2509	9917	10470	683
2013	23473	2587	9667	11219	670
2015	23478	2588	9663	11227	685

Source: SFR 2001-2015, Forest Survey of India

Table.4 Change matrix of forest cover class of Jharkhand (Km^2)

Year	VDF	MDF	OF	S
2003	-106		185	-169
2005	0	2	20	0
2007	-5	7	170	7
2011	0	18	65	0
2013	-3	-250	749	-13
2015	1	-4	8	15

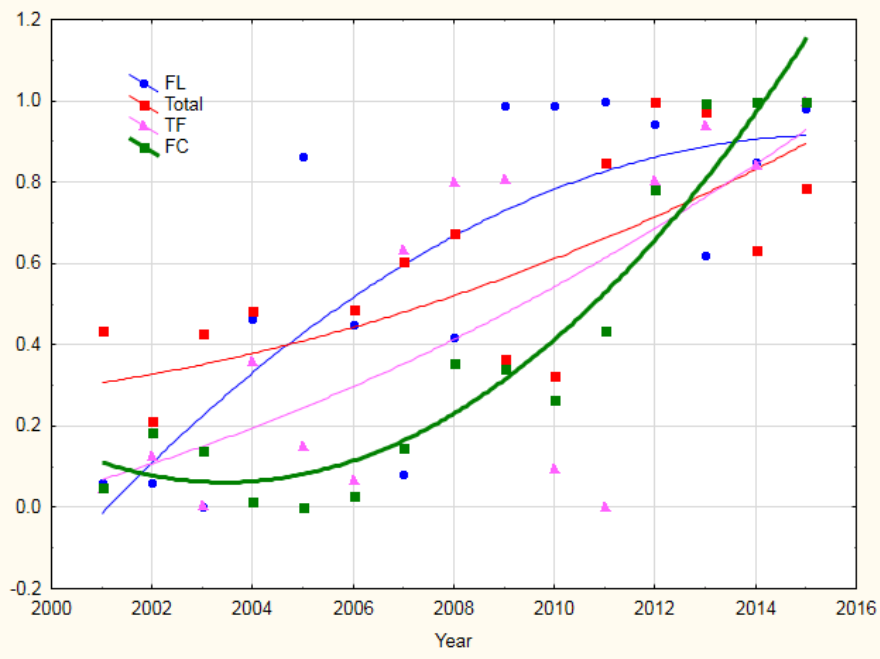
Source: SFR 2001-2015, Forest Survey of India

Table.5 Classification of forest density

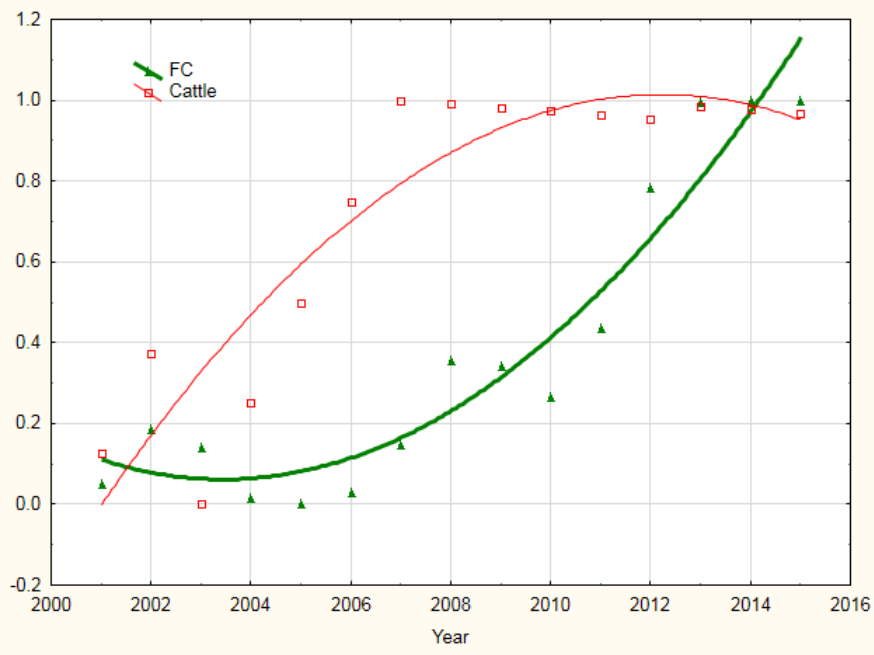
Forest class	Density in percent	Weight (W)
Very Dense Forest	100-70	0.50
Moderately Dense Forest	70-40	0.32
Open Forest	40-10	0.15
Scrub	10-0	0.03

Fig.1 Map showing the study area (Jharkhand state) of India

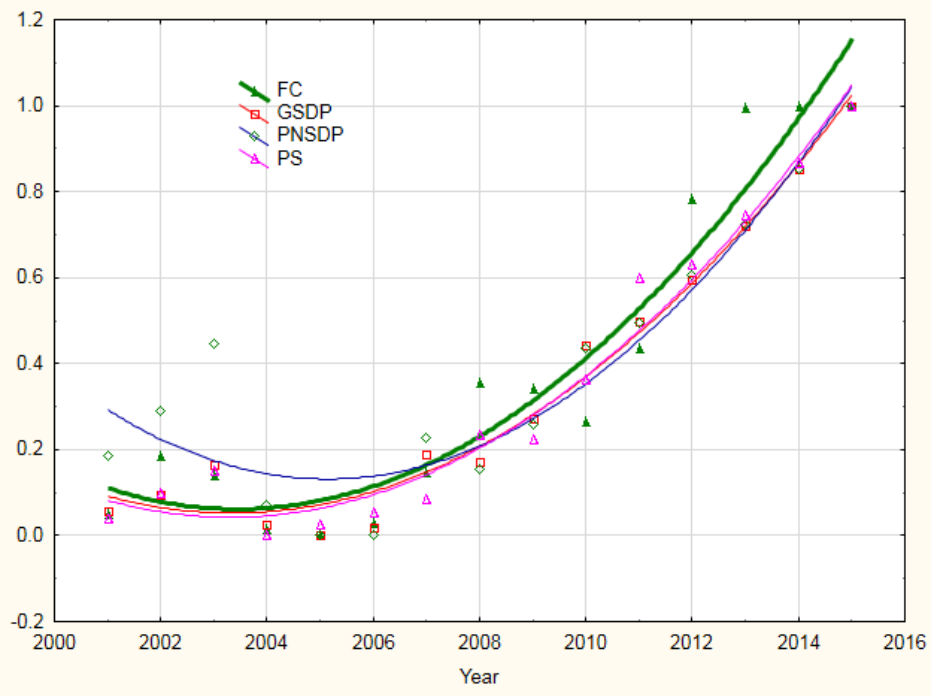
Graph.1 Comprehensive framework of forest transition with agricultural sector



Graph.2 Framework of forest transition with livestock population



Graph.3 Comprehensive framework of forest transition with economic parameters



Increase in agriculture production provides an opportunity for the employment. Expansion of agriculture into forestland in developing economies is the major strategy to increase agricultural production and income (Angelsen, 1999, Culas, 2012). However, forests remain an important source of various products and services of forests that

contribute to households' welfare, and act as secondary livelihood options to large number of the region's rural households (FAO, 1998; FAO, 2012). Demand of agricultural and forest products can cause deforestation with the increase of income levels, while high incomes can reduce pressure on forests due to demand of protection of forest (Culas, 2012).

Livestock is an integral part of livelihood opportunities for communities residing in the rural section of the society and it does reflect land use intensification. The collections of fodder for the livestock are mostly from forests and agricultural fields, and grazing in the forests lands. However, due to expansion of forest land and increase in agricultural production, the fodder dependency of livestock from the forests has significantly decreased. This has positive impact on forests transition. The livestock production may act as an important income improvement opportunity for the rural population, and thus reduce the overall dependence on the forests, which in turn may facilitate transition.

Forest regulation and policy interventions helped the forests, and agricultural expansion in the state, which did not happen at the cost of forests entirely (FRI, 2013). Government intervention plays a crucial role in determining changes in forest cover. The regulatory policies adopted by the state influences the competing land use and thus the occurrence of forest transition takes place (Barbier and Tesfaw, 2015). This can be achieved in several ways such as through political stability in low and middle-income countries (Grainger, 2004; Grainger and Malayang, 2006; Mather and Needle, 1999), regulatory institutions for implementation of policies (Mather, 2007) or by the rule of law and protection of property rights.

The theory on forest transition suggests that there is a complex relationship between forest cover and modernization and economic development of the nation or region. As a general principle, with an increase of GDP, consumers progressively demand improved quality of life (e.g. Maslov, 1943) due to the GDP linked development (Redo *et al.,* 2012) and hence GDP increase will lead to demand for better quality resources, including wood resources through imports. State Gross Domestic Products and state GDP per Capita was slow during the early period. Rate of deforestation was high during that period; however, the deforestation started to decline and the fate of reforestation accelerated with the subsequent increase in incomes. This will result in an overall reduction of forest dependence and a reduction of pressure on forests (Kant and Redantz, 1997) and thus likely to have positive impacts on forest cover.

The results revealed after applying the stepwise multiple regression model, that the livestock population particularly cattle population and fallow land under the land use classification are the significant drivers to the weighted forest cover change at 5 per cent level of significance leading to occurrence of forest transition in the state. The overall model was significant (p = 0.000) at 5 per cent level of significance with the value of adjusted R^2 as 0.83. Weighted forest cover and cattle population are directly related. Theoretically, the increase in cattle population might exert pressure on forests, but due to continuous increase in agricultural production and productivity especially through expansion of the fallow land leads to forest recovery, especially if agricultural land is abandoned (Mather *et al.,* 1999).

Livestock has always been accountable for deforestation but increase in cattle population, as in Jharkhand, leads to more possibilities of livelihood for the rural people. Consequently, increase in fallow land and

cattle population reduced the pressure on forest which in turn allowed recovery of forest cover in Jharkhand. These conditions reckon the forest transition in the state that is likely to occur with government interventions. Furthermore, effective government efforts or good governance is required in turning the trend of deforestation into afforestation, especially when changes are associated with economic development as well as changes in land use particularly through the expansion of the fallow land. It is important to realize that good governance hastens the time when forest transition occurs whereas worse governance delays it (Barbier and Tesfaw, 2015).

Forest scarcity path and *economic development path* are the two important pathways identified by Rudel *et al.,* (2005) based on a cross-national study for the 1990s. Changes in national forest policies play a central role in stirring the forest transition leading to another path known as *state forest policy pathway*. Kull *et al.,* (2007) associated globalization with forest cover leadint to forest transition and given the fourth pathway as *globalization pathway*. The most recent path named as *smallholder, tree-based land use intensification pathway* was based on the studies on smallholders and tree based land use. Based on the finding of the study of Jharkhand, a new path may be proposed as *mixed farming practices pathway*.

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