# Forest Area and Land Use Change in Pakistan: A System Dynamics Approach

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# Forest Area and Land Use Change in Pakistan: A System Dynamics Approach

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**Abstract**

*Deforestation is a global environmental problem caused by a wide range of drivers which may vary from one region to another. Pakistan with low area under forest is facing very high level of deforestation. The present research aims at incorporating the selected drivers of deforestation in to systems thinking to find out the effects of these factors on forest area of the country. These selected variables; population growth, timber and firewood production, forest land use conversion to agriculture and construction, and forest area affected by forest fires have been studied from 1990 to 2010. The results show that, without interventions, deforestation is projected to increase further, thus slowing down the growth of forest area. The effects of forest production on deforestation are not evident. The policy scenarios developed through system dynamics show that afforestation and regeneration efforts can be more effective than population control and production control policies. As shown in one of the system dynamics scenarios, to achieve national forest regeneration goals, the Pakistani government should create a multi-dimensional policy covering land use policy, forest production control, population control and forest growth policy through afforestation and regeneration. The model results are validated and found consistent with the national forest area.*

***Key words:*** *Pakistan, Deforestation, System Dynamics, Forest area, Projection*

## Introduction

Forest area in Pakistan covers 5.1% (4.55 m. hectares) of the total land area of the country. Out of this, coniferous and natural forests constitute 54% and are the main source of construction wood (Bukhari, Haider and Laeeq, 2012). Pakistan already has low forest cover. It ranks 113 among 140 countries of the world in terms of forest area (GOP, 2005a). Per capita forest area in Pakistan is only 0.03 ha. and is declining due to growth in population (NIPS, 2009). In 1992, a

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The Authors are thankful to Philip Grabowski, PhD. Scholar, Dept. of Community Sustainability, MSU. for his valuable suggestions in building the model.

Forestry Sector Master Plan (1992) was prepared to increase the forest area to 10% by 2018[3] but there is no significant increase. The Government of Pakistan highlights the Forestry Sector Master Plan (1992) estimate of annual rate (4%) of decline in growing stock in its National Biodiversity Action Plan (1999). A complete national inventory of forest growing stock is not available in Pakistan. The working plans of the forest department cover approximately 50 % of coniferous forests and contain estimates of volume, but many of these are based on outdated inventories (FAO, 2010a). The household sector is the largest consumer (81.8%) of fuel wood, followed by industrial fuel wood users (14.9%) and commercial users (3.3%) (Zaman and Ahmad, 2012). Protection forests are 58.5% of the total forest area and production forests are 41.5% (GOP, 2005).

The forest growth *(yield)* in the country is 14.4 million $m^3$ which is assumed as sustainable annual wood supply. The wood shortage was estimated about 34.12 million $m^3$ in 2010 which is 70% of the total wood consumption. Out of the total imports of wood and wood based products, the imports of timber constitute 76% while the imports of wood products constitute 20% (GOP, 1992; GOP, 1994; GOP, 2005; Zaman and Ahmad, 2012). The main sources of fuelwood are farmlands and plantations (91.4%) followed by imports (5.22%) and state forests (3.34%) (GOP, 1992; GOP, 2005).

About half of the area under forests in the developing countries was cleared between 1900 and 1965. Keeping the current rates of deforestation in mind, the rest is likely to disappear in 50 years (UNESCAP, 1986). Pakistan since 1992 is losing about 13000 hectares of forests every year (a .36% deforestation rate). The total area under any sort of forest and rangeland vegetation cover has decreased by 1.68% (PFI, 2004). The rate of conifer forests decline in Pakistan has been 1.27% per annum since 1992. Over a ten year period (1992-2001) the decline was -2.3%, and in subsequent ten years (2001-2010) a decline rate of 0.28% has been observed (Ahmad et al., 2012). Deforestation rate is estimated as between 1.66% to 2.1% and annual loss of forest is 0.043 million hectares[4]. World Bank (2009) has estimated the annual rate of deforestation in Pakistan as 2.1%. Rare data is available for the forests affected by fires in Pakistan (FAO,

[3] National Communication to the UNFCC; http:www.fao.org/docrep/003/x6900e0o.htm

[4] http://rainforests.mongabay.com/deforestation/2000/Pakistan.htm). (http://prr.hec.gov.pk/Chapters/81S.1.pdf accessed on February, 2nd, 2015

2010a). A study conducted in 2000 revealed that an area of 49,986 ha, i.e. 1.27% out of 3.950 million ha, surveyed is affected annually by forest fires (FAO., 2009).

FAO (2009) conducted a study by using time series linear trend analysis for different forest types at the country level including Northern Areas and Azad Jammu and Kashmir for the years 1992, 1997 and 2001 and projection was made for 2005, 2010, 2015 and 2020. The results predicted a decrease in total forest area of Pakistan at a rate of 28,000 ha per annum till 2020. In other words, the total forest area of Pakistan was likely to be 2.78 million ha in 2020 versus 3.29 million ha in 2001. The extent of reforestation in the hilly forest area of Pakistan is negligible compared to the rate of deforestation (Qasim, Hubacek, Termansen, and Fleskens, 2013).

Most of Pakistan's forests are in the mountainous areas are usually held by tribal communities where customary laws are prevailing. Documentation of forestlands and rights are rare and conflicts are common (Wani 2001; Jacoby and Mansuri, 2005). Decisions about forest management, fines, roles and responsibilities, and enforcement are made either by the *Jirga*[5] or in village meetings (Shah and Husain, 1998). Statutory law related to land rights in Pakistan is outdated and incomplete. There is no specific comprehensive law that governs land matters but a variety of laws deal with this issue. Provincial revenue legislation provides for landholding categories, recordkeeping, land transactions, surveys, and partition (Khan, 1981; USAID, 2008).

A study conducted by Nazir (2009) analyzed the effects of socio-economic factors on the forest area of Pakistan using multiple regressions with seventeen explanatory variables. About 94% of the total effect is explained by the variables included in the study. Cultivated area has been found as a factor with highest unit of effect (3.4%) on forest area of the country, followed by construction area. The effect of cultivated area is even higher (8.1%) in the forest rich area of Pakistan, NWFP, presently called Khyber Pakhtunkhwa. However, this methodology did not allow the development of future scenarios and linkage effects of the driving forces of deforestation. The present study is an attempt to analyze Pakistan's deforestation problem using a system dynamics approach.

**Land Use and Land Use Change Trends**

In Pakistan, analysis of the land cover change maps show that agriculture mostly expanded on rangeland and forestland. Agricultural contraction was also observed mainly because of

[5] Jirga is a communal gathering, act as a court held by elders of the community where decisions are made by elders and the community is suppose to follow them. These decisions are mainly in accordance to the customs of the area.

construction of housing and infrastructure. At the same time, some cases of agricultural abandonment are observed, which were mainly caused by the expansion of built-up land such as housing and infrastructure (Qasim, Hubacek, Termansen, and Fleskens, 2013).

Land use change in a mountainous area of Pakistan situated in the Hindu-Kush Himalayan region has been studied despite data limitations. Geophysical and geographical factors related to land use change over the years 1968, 1990 and 2007 showed that at high altitude there is 30.5% loss in forest area, out of which a third is caused by agricultural expansion. In the lower altitudes, total agricultural expansion was 129.9 % that consumed 31.7 % of the forest area over a forty-year time period. In the middle elevation, forests decreased by 49.7% and agriculture expanded by 70.3%. Annual deforestation was high at low altitudes and vise versa, with deforestation rates ranging between .8% and 1.86%. At high altitude, geophysical factors such as slope, aspect and altitude were the responsible factors for land use change and agriculture expansion rather than the distance to roads and city. At low altitudes, accessibility was the main factor responsible for agricultural expansion and land abandonment. Most of the deforested land has been converted to agriculture or as rangeland. In two parts of Swat district; rich in forest area in Pakistan, around 75% and 37.8% of the forest area was converted to rangeland over a 40 year time period (Qasim, Hubacek, Termansen, and Fleskens, 2013).

Construction is also potentially a large driver of deforestation in Pakistan while the country becomes wealthier and more urban. The construction sector in Pakistan has a 2.3% share in the Gross Domestic Product. Its growth rate was recorded at 17.2% in 2006-07 (Khan, 2008). The annual growth rate of housing in urban areas was 8% in 1998; this rate was the same (8%) in 2009 (GOP, 2011). There is a high demand for construction workers that is reflected in a continued double-digit rise in their wages since 2005. Their wages increased by 11.1 percent in 2007. It has been found that there is a strong causal relationship between the aggregate economy and the construction sector of Pakistan from 1950 to 2005. The construction flow precedes GDP whereas GDP does not precede construction flow (Khan, 2008). In Asia, particularly, urbanization often spreads on prime agricultural land thus reducing production potential. Agricultural production has been achieved first by intensive use of land resources, and later through expansion in agricultural land which has impacted forests (Saeed, 2000).

Deforestation is one of the most important and most intensively studied factors in land use change processes (Qasim, Hubacek, Termansen, and Fleskens, 2013). Deforestation refers to the

clearance of forests for agriculture and other land uses (Bass et al., 1997; Campbell and Sayer 2003). Deforestation is mainly the conversion of tropical forest to agricultural land (FAO., 2010a).

**Study objectives**

The main focus of this study is to determine the effects of drivers of deforestation on forest area of Pakistan in the coming decades and to determine the desirable rates of change in these variables which could otherwise help to save the forests from further depletion.

**Limitation of the Study**

The subject of deforestation covers wide range of variables including factors for which either the data was not available or very limited for example, time series data for forest fires, illegal extraction of forest products, forest land conversion to another land use category. The study covers those variables for which the data was available. However the data is estimated for few variables used in the system dynamics.

**Methodology**

There is hardly any study addressing the forestry sector problems of Pakistan through system dynamics. A study by Saeed (2000) used system dynamics with Pakistan inclusive in a sample group of Asian countries. Area under forest was one of the factors. However, the focus of the study was to examine growth in the agriculture consumption base.

The present study uses system dynamics to estimate the effects of drivers of deforestation on the forest area of Pakistan. The main drivers of growth in forest area are selected as afforested area and regenerated area. Since the forest area managed under regular working plans by the Forest Department of Pakistan is only 1.82 million hectares (PFI, 2004), a minimum area of 0.07 million hectares (70000 hectares) is considered as natural regeneration. The main drivers of deforestation are identified as forest fires, population growth, expansion in cultivated area and construction area, growth in rangeland area, and collection of firewood and timber.

Further, the net growth in forest area would be calculated by considering area afforested, area regenerated and subtracting deforestation. We assume that 5% of the total expansion of

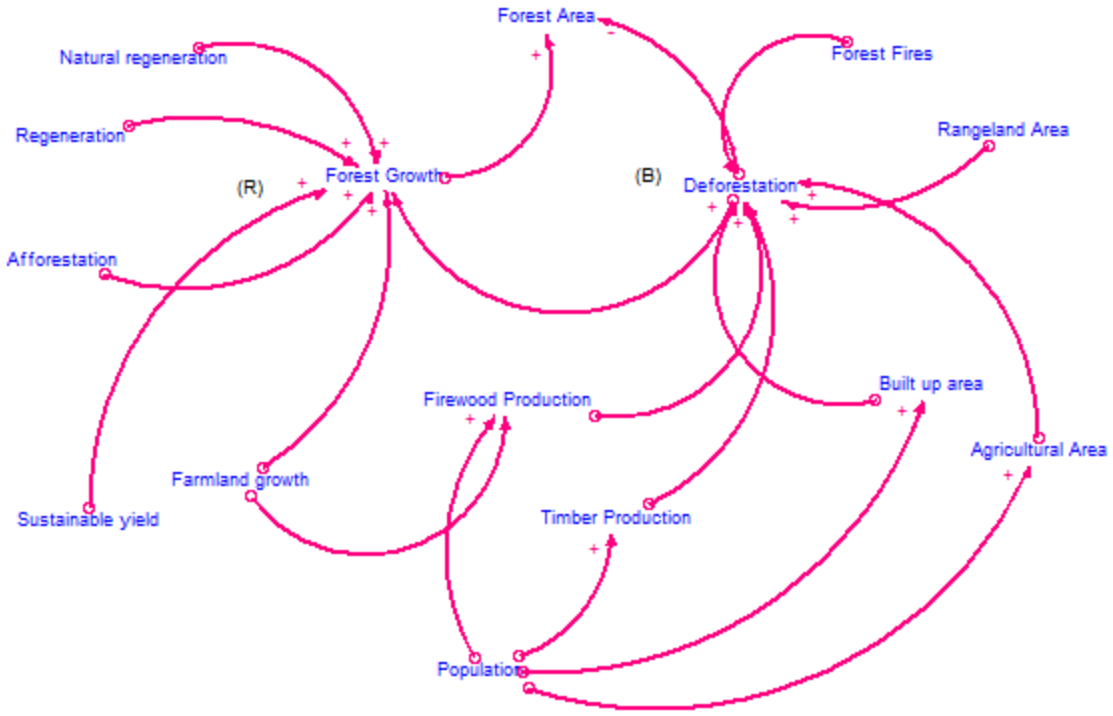
cultivated area and 5% of the built up area is considered as contributing to deforestation. This conversion rate makes model outcome consistent with forest area as shown in the national statistics.

The methodology covers two aspects; one aspect is to calculate the rate of change in the selected variables over twenty years of time from 1990-91 to 2010, and the second aspect is simulating forest area from 1990 to 2050 using system dynamics. Sensitivity analysis is conducted using four potential interventions: Land use control policy, controlling Forest production, Population control policy and Forest area growth policy. A combined policy that considers all policy scenarios simultaneously is also applied. Population control policy aims at reducing birth rates compared to the present level. For land use policy, we consider a scenario between 1% and 5% of the expansion of both cultivated area and built up area at the cost of forest area. Forest production control policy aims at cutting down the production of timber and firewood to a minimum half of their present level.

## Causal Loop Diagram

The causal loop diagram is depicted to show the feedback loops, reinforcing and balancing for the forest degradation system dynamic model.

**Figure 1: Conceptual map of Forest area degradation showing reinforcing and balancing loops.**




**Results and Discussion**

The results in the table 1 show reduction in areas of some land use categories, land not available for cultivation, barren land/snow area and culturable waste areas. There is no significant change in the reported area as assumed in the study model. In other words expansion in built up and cultivated area is at the cost of other land use categories including forest area. There is only 1.2% per annum increase in forest area. On the other hand agriculture land area has also increased at a rate of 1.2% per annum. The rate of rangeland area has expanded at the rate of 1.96% annually. It has been observed that there is a great expansion in urban built up areas at a rate of 22.5% per annum during the period 1990-2010.

**Table: 1: Change in Land use Areas over Twenty Years (1990-2010)**

| Factors | 1990-1992 | 2010-11 | Increase/Decrease in Twenty Years | (%) Change over Twenty Years | Per Annum Change |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Geographical Area (m. hec) | 79.61 | 79.61 | ---------- | ---------- | ---------- |
| Reported Area (m. hec.) | 57.61 | 57.76 | 0.15 | 0.3% | 0.015% |
| Forest Area (m. hec.) | 3.46 | 4.26 | 0.8 | 23.12% | 1.2% |
| Not Available For Cultivation (m. hec) | 24.34 | 23.53 | -0.81 | -3.4% | - 0.17% |
| Culturable Waste Area | 8.85 | 7.82 | -1.03 | -11.6% | - 0.58% |
| Agriculture Land (%) of the land area | 23.4 | 28.9 | 5.5 | 23.5% | 1.2% |
| Rangeland (%) | 32.4 | 45.1 | 12.7 | 39.2% | 1.96% |
| Water Bodies (%) | 1 | 1.9 | 0.9 | 90% | 4.5% |
| Urban Built Up Areas (%) | 0.2 | 1.1 | 0.9 | 450% | 22.5% |
| Barren land/snow area (m hac.) | 26.89 | 11.822 | -15.8 | -58% | -2.9% |
| Water bodies (m hac) | 0.913 | 1.677 | 0.764 | 83.6% | 4.1% |

Source: Calculated on the basis of data taken from Land Cover Atlas of Pakistan, PFI. 2004

The data shows change in main drivers of forest growth and deforestation over a twenty year period. It has been observed that urban population growth is very high (4.4% per annum) thus is a main cause of expansion in urban built up area (22.5% per annum). However, cultivated area growth is 0.3% per annum. Agricultural land area is expanding at a higher rate (1.2% per annum), other land categories included in the agricultural land area may be more responsible for the depletion of forest area; for example, rangeland expansion (1.9% per annum).

Timber and fire wood production are other drivers of deforestation. Fire wood production has increased 9.9% per annum. The main source of fire wood is farm- lands (90%), rather than state forests (which contribute only 10%). Timber production has shown a declining trend (-4.2% per annum) during 1990-2010. This is hard to accept with the growth of population at 2.7% per annum during these twenty (20) years. A commercial timber harvesting ban has been imposed in the country in 1993, resulting in a decline in legal harvesting and marketing and expansion in illegal cutting and trade ten times higher than the recorded timber out-take (Fischer et al., 2010). There is a reduction of 63% and 80% in legal production of timber and fuel wood respectively after the ban (Zaman and Ahmad, 2012).

In forest growth, the area afforested and area regenerated play a vital role. Over the years from 1990-2010, there is a reduction in afforested area at 15.4 % (- 0.77% per annum). However, regenerated area over twenty years has increased at 93.8% (4.7% per annum).

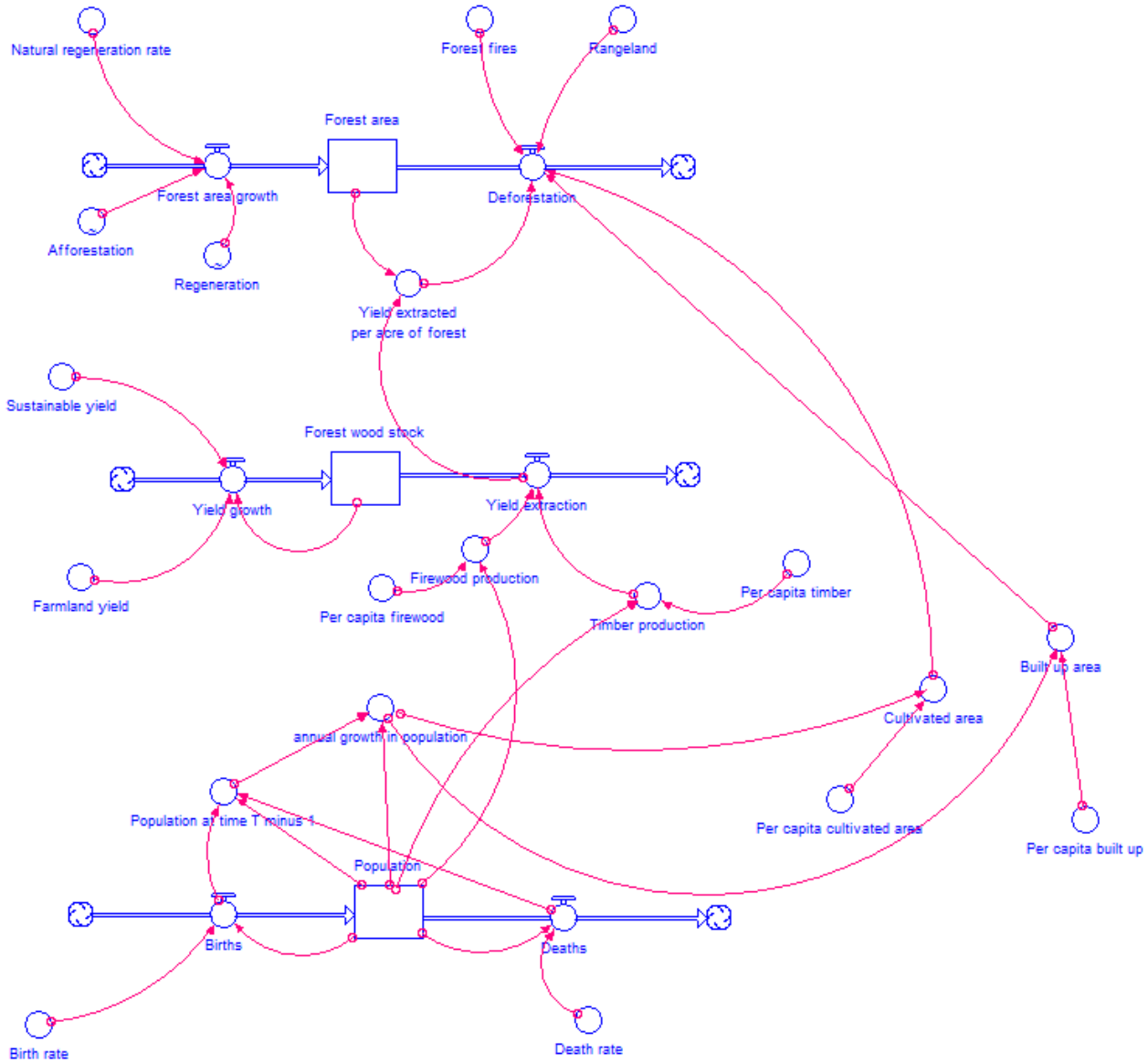
The annual forest growth (yield) is estimated at 14.4 million $m^3$, assumed as sustainable wood supply (GOP, 1992). By combining data from Forest Department working plans, the farmland tree survey and the Household Energy Strategy Study (HESS), the Forestry Sector Master Plan estimated a total national standing volume of 368 million $m^3$(EC-FAO, Dec. 2002).

**Forest area, Forest Area growth and Deforestation: Analysis and Projection**

The model was set up with forest area and deforestation as main components with the aim to develop a systems thinking for the drivers of growth in forest area and drivers of deforestation keeping in mind its consistency with the national data. Despite the time series data limitation for some variables the model considered all important variables and tested the sensitivity analysis. In order to understand how much forest area is affected by deforestation, we first developed a basic model to use as reference mode incorporating deforestation rates given by FAO (2009), World Bank (2009) and PFI (2004). This exercise helped us to know that either the deforestation rate is lower than what the literature is showing or the forest growth rate is higher than what the governments' afforestation and regeneration activities are showing. The later case was much consistent with the systems thinking keeping in mind the drivers of deforestation such as population growth, land use change and conversion, forest fires, and production of wood. In other words, if we add the figures of all these drivers together, deforestation would be even higher than what the national statistics are showing. Therefore in order to bring the forest area at par with the national figures from 1990-2010, natural regeneration of forest was considered in the model. However the model was tested with and without the natural regeneration and the results were discussed comparatively. The model was then adjusted with variables forest yield and land use categories. The forest yield growth was derived using farmland growth and sustainable growth. The provision of farmland wood availability decreases the pressure from total forest wood stock availability. The forest yield extraction in the form of firewood and timber is affected by the total population of the country every year. The land use categories

mostly effecting forest area are cultivated area, built up area and rangeland areas. The past trends of expansion in these three areas show that with the annual growth in population built up and cultivated areas are expanding, however the rangeland area is not affected by annual population growth. Next, the model was built taking a time step of years; the national forest area remained consistent with the model variables from 1990-2010, and projection was carried out till 2050.

**Fogure 2: Model showing Forest area and Deforestation in Pakistan**



- **Forest Area and Deforestation**

At present rates of population growth, per capita firewood and per capita timber production along with 5% expansion of cultivated area and built up area at the cost of forest area, the deforestation area is also increasing every year and the forest area would be increased to only 5.1 million hectares by 2050. This area is still less than the 10% forest cover proposed by the government. If the government wants to increase forest area to 10%, it has to control deforestation by controlling the growth of population, production of timber and firewood and expansion of cultivated and built up area at the cost of forest area. The forest area after 2035 would be increasing at a slower rate than the past. Following this trend the forest area would reach to maximum 5.6 million by 2050 and after that it would start declining.

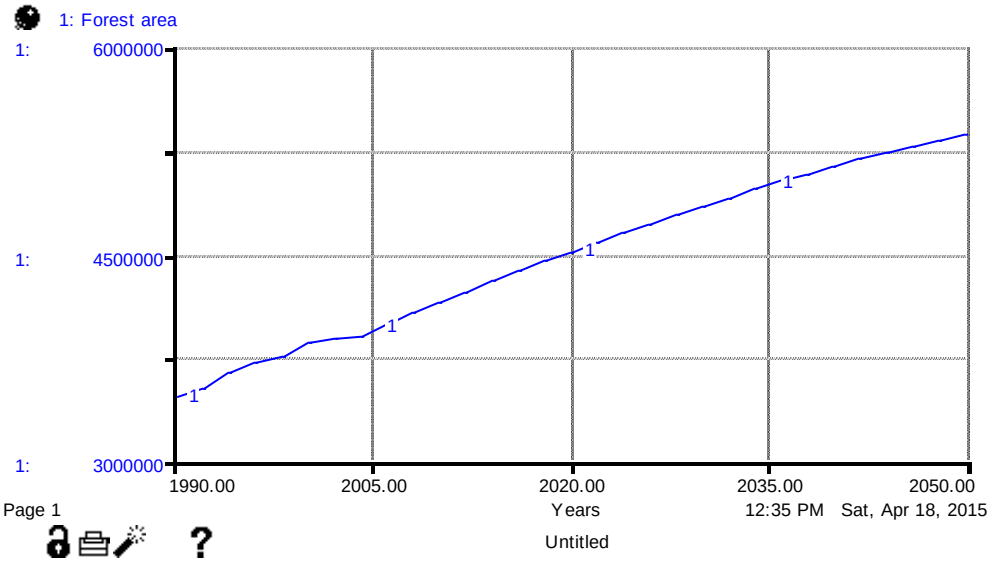



Figure 3: Forest area and Deforestation (Hectares)

- **Agricultural area and Built up area Expansion**

  Built up area and agriculture areas are growing with the annual growth in population. The model has considered only 5% of the expansion of the total agriculture area and total built up

area at the cost of forest area. Any level higher than 5% makes the model result inconsistent with the national data. Built up area would contribute more to deforestation in future.

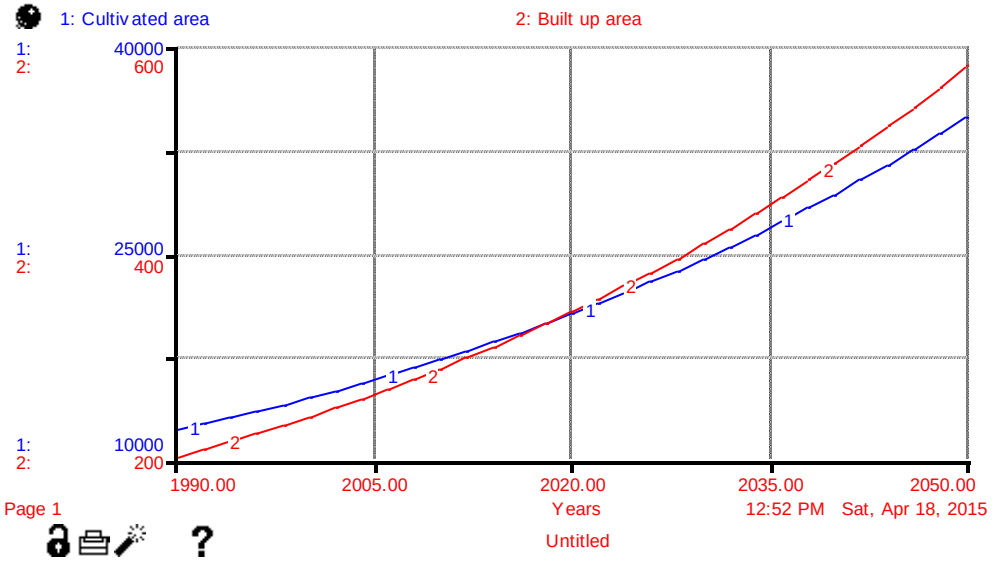



Figure 4: Agriculture and Built up area expanding at the cost of forest area (hectares)

- **Firewood Production**

  Firewood production, considering per capita firewood production (average firewood production value for the years 1990-2010 with population 112.27) results in increase in total firewood production to 647.6 thousand cubic meters at the end of year 2049-50 (Figure 3).

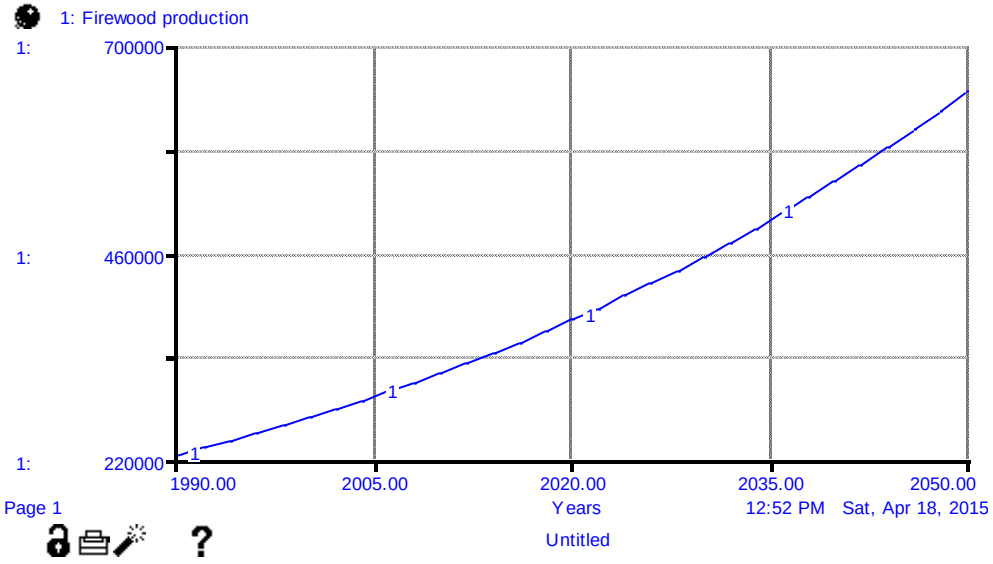



Figure 5: Growing trends in Firewood Production

- **Timber Production**

  Timber production, considering per capita timber production as 0.0023 (with average timber production figure and minimum population from 1990-2010) would increase as population is increasing thus reaching 744.8 thousand cubic meters by 2049-50.

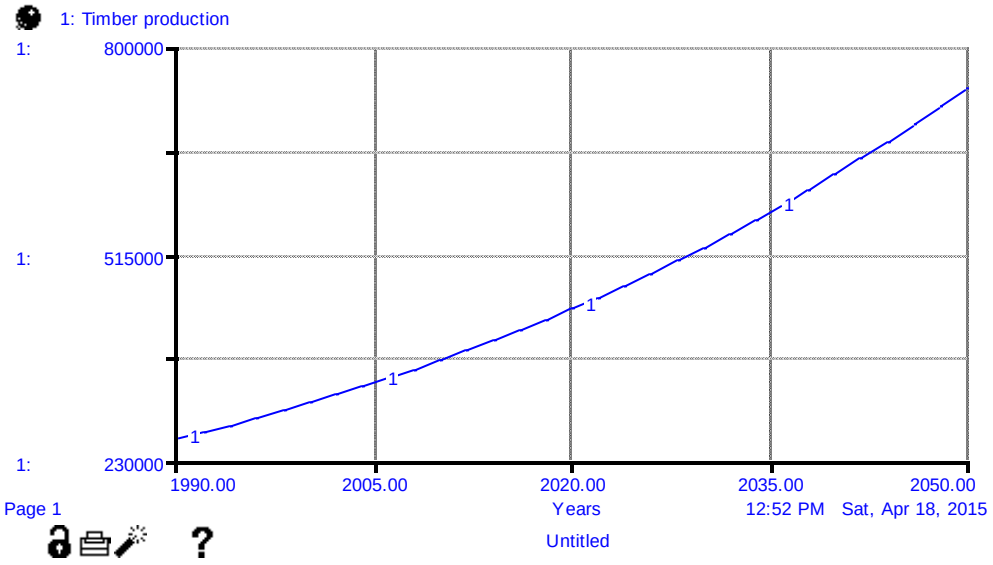



Figure 6: Increase in Timber Production

- **Population Growth**

  With a crude birth rate of 25.4 per thousand and a crude death rate of 7.43 per thousand as between 1990-2010, the population would be about 323.8 million in 2049-50 as shown in Figure 5.

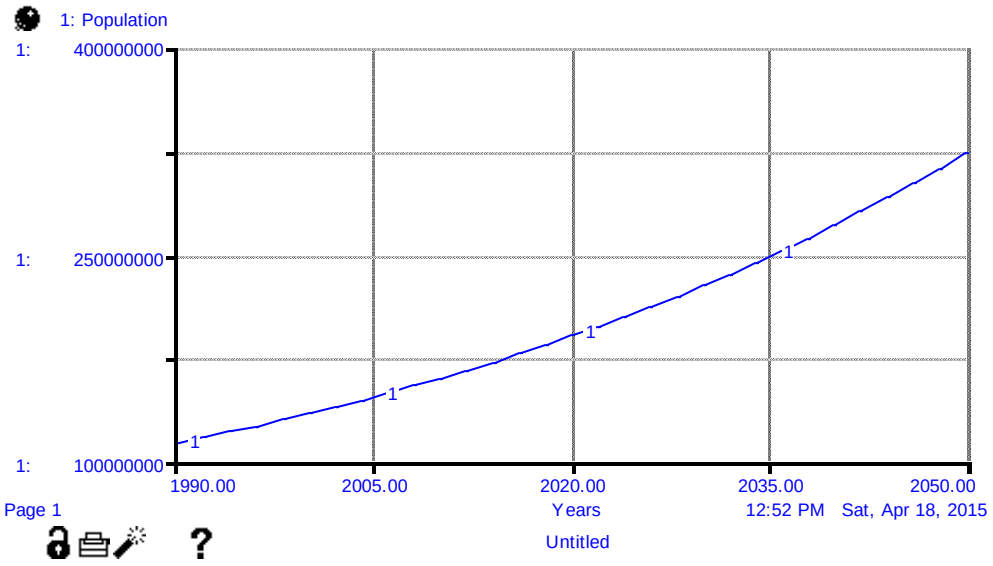



Figure 7: Population Growth over time

**Sensitivity Analysis**

We built sensitivity analysis on the basis of increasing the area under forest through enhancing the efforts of afforestation and regeneration and decreasing the level of deforestation in the country by birth control policy, land use policy and control on forest production (timber and firewood). We set the birth rate value between 10 per thousand and 26 per thousand. The uniform distribution value for timber and firewood production is set ranging between present production and half of the present production per capita level of 0.0023 and 0.002 respectively and for land use control the value ranges between 1% and 5% of agriculture and built up areas' expansion at the cost of forest area.

1 **Population Control policy**

The results show that since population control policy has a significant delay in its effects on the forest, it would not be very effective at increasing forest area in the short run. Its effects would be visible after 2035. It results in increase in forest area to 6.5 m hec. in 2050 only up from 5.3m hectares which otherwise could be achieved in the absence of population control.

2 **Forests' Production Control Policy**

Forest production control policy is found insignificant and ineffective alone both in the short run and long run. These results are supported by the literature cited above that the forest harvesting ban has resulted in controlling legal forest production only. The data is not available for illegal harvesting. Secondly fuel wood needs are mostly met from farm lands. Forest area would be increased only to 5.6 in 2050 by selecting legal harvesting to half of the present level.

### 3 Forest Growth Policy

The government efforts for afforestation and regeneration are limited. If we keep on increasing the afforestation and regeneration rate from the present average level of 23150 hectares and 25600 hectares respectively to double, we would be able to increase the forest area to 8.5 million hectares in 2050. This policy seems to be more effective than other policies mentioned above.

### 3 Land use control policy

Land use control policy by controlling forest land conversion to agriculture and built up area would help to increase forest area to 5.3 million hectares by 2050. In the absence of land use policy in the country, with annual growth in population, the expansion in cultivated and built up area is going on thus effecting forest area. The results show that the forest area would be growing at a slower rate after 2018. The rate of this growth would be further reduced in the following years till it would start decreasing after 2050.

## 5 Multiple Strategies

If multiple strategies are adopted including land use control, population control, forest production control and forest growth policy through afforestation and regeneration, the forest area would be increased to 7.5 million hectares by 2050.

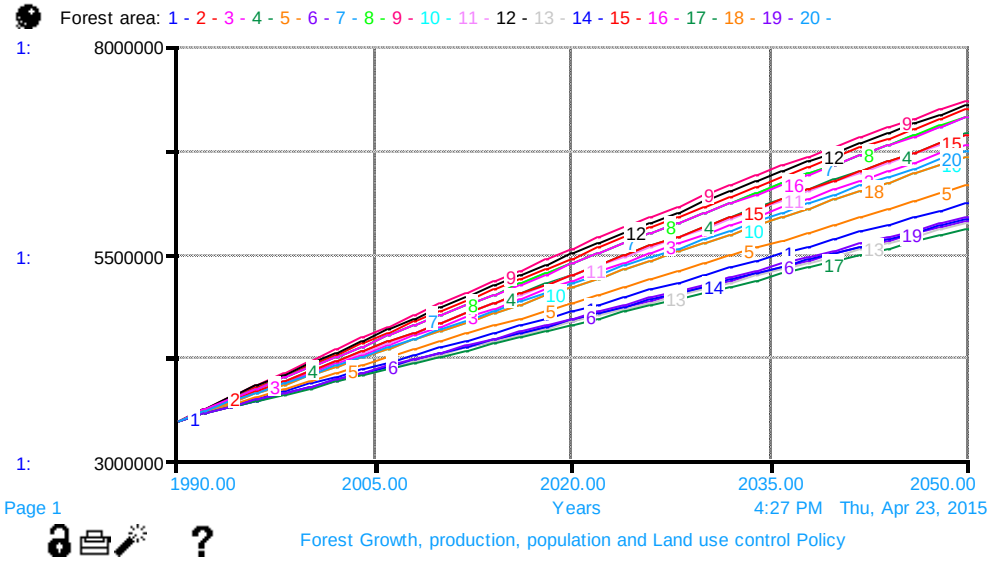



Figure 8: Forest Growth, Land Use, Forest Production and Population Control Policies affecting forest area

In case multiple strategies are adopted, deforestation in 2050 would drop down to 0.075 m hectares from 0.102 m hectares in the absence of all these policy controls during the same year.

**Model Validity**

The rationality of the model has been checked with the help of literature and national statistics. The forest area from 1990-2010 mentioned in national statistical documents (Economic Survey, 2014-15) and model results are consistent.

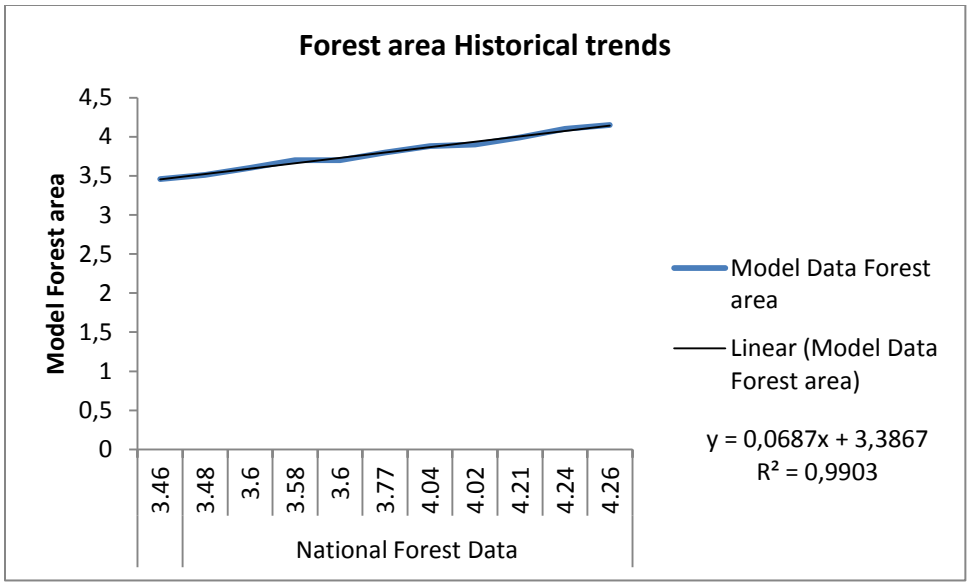



Figure 9: Model data showing consistency with National forest data

**Conclusion**

System dynamics methodology for forest land of Pakistan helped us to determine the effects of drivers of deforestation and to estimate the net position of forest area. It further helped to determine the information lapse, if any, to construct the model. By developing scenario visioning the projection was useful in fixing the problem. Deforestation in Pakistan is not a uniform figure for every year rather growing with the growth of population and expansion in cultivated and built up areas. As shown by the results of the study, there is no significant change in the reported area of the country therefore we accept that a part of the total expansion in the cultivated and built up area is at the cost of forest area which will keep on going in decades to come. Forest production is found insignificant in the absence of data on illegal harvesting, that is not available therefore non-inclusion of this factor is the limitation of the model. Afforestation and regeneration activities are found insignificant unless accompanied by natural regeneration. Some policy scenarios are found effective like land use policy and forest growth policy. The model data is valid for the historical data found in the national statistics.

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