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Forest Wood Consumption and Wood Shortage in Pakistan: Estimation and Projection through System Dynamics

NAILA NAZIR, LAURA SCHMITT OLABISI, and SALMAN AHMAD

Consumption rates of major forest products such as timber and firewood, place significant strain on wood stock and forest area in Pakistan. With the country's rising population, the consumption of these two major products is increasing because of the growing energy demand, and no alternative products are likely to replace wood consumption in the near future. We apply system dynamics modelling to an analysis of the forestry sector in Pakistan for novel insights into the drivers and future trajectories of wood consumption. The present research is based on time series macroeconomic data from 1990-2010 and projections to 2040 of wood supply, forest area, population growth, wood extraction, wood imports and different uses of wood in the country. The study reveals that there is no significant increase in area under forest, while consumption of firewood and timber has increased. The consumption of firewood is greater than timber consumption in Pakistan, both in percentage share and in total volume of wood consumption. The sustainable supply of wood is less than wood consumption, and with population growth this gap is increasing; wood supply from agricultural lands is a viable option to fill the gap.

Keywords: Wood Consumption, Sustainable Wood Supply, Projected Wood Shortage

I. INTRODUCTION

The forestry sector's contribution to Gross Domestic Product (GDP) in Pakistan was 1.2 percent in 1990, decreasing to 0.6 percent in 2011 [FBS (2014)]. If farmland forestry products are included, the forestry share would increase to 1.58 percent to the GDP. The forestry business generates revenue that is equivalent to 10 percent of the country's exports [FAO (2009a); FAO (2014a)].

In a country where the forest area is very low and deforestation rate is high, it is imperative to look into the forest wood resource supply and consumption. There is a consensus that high population growth, over-exploitation of wood resources, over-grazing and poor land-use management are the main causes of deforestation [Ouerghi (1993); NIPS (2009); Mather and Needle (2000); Qasim, *et al.* (2013)]. In developing countries, wood energy represents approximately 15 percent of the total primary energy

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consumption [Trossero (2002)]. The share of Pakistan's consumption of conventional wood and biomass energy, as a portion of the total energy in 1993-94 was 46 percent [FAO (1997b)]. The FAO (2009a) estimated that the share of wood energy as a portion of rural energy consumption in the country is 37.52 percent. Despite a high level of dependence on wood biomass, there is no data or insufficient data for wood supply and consumption in Pakistan [Nazir (2009)]. This presents a barrier to natural resource planning [FAO (1997a)]. Information regarding the use of fuel wood and traditional fuels was mainly based on rough estimates, until the Household Energy Strategy Study (HESS) was undertaken [Ouerghi (1993)]. Khalil (2000) also pointed out that in Pakistan the major constraints in environmental resource valuation are irregular and unsystematic data collection across authorities, responsible for data collection; the absence of complete sets of data and absence of data adequately describing the multi-disciplinary environmental and cross resource issues. The values of total consumption of wood in Pakistan are based on per capita wood consumption [see for example, Pakistan (2005); Mathtech (1988); Sheikh (1990); FAO (2009a); Clark (1990)]. Some studies consider sources of wood supply in the country, but lack time series data on the volume of wood supplied by each source [Clark (1990); Pakistan (2005, 2010)].

There is a need to add data and analysis to the on-going efforts to construct data sets for natural resources in Pakistan. Estimating and forecasting domestic wood consumption is also important to check the patterns, prices of wood and import of wood products. The present research is one such effort that focuses on estimating and projecting few key variables related to wood consumption, wood supply and sustainable wood supply in the country.

Economic and environmental management uses several different tools for estimation and analysis. Different modelling techniques are used to address natural resource issues, for example, Geospatial techniques [Bhalli, *et al.* (2012)]; Spatial explicit models, Aspatial models [Seto and Kaufmann (2003)]; Multi-agent systems models [Parker, *et al.* (2003)]; Stochastic models and Behavioural models [Irwin and Geoghegan (2001)]. Simulation or mathematical modelling is an important tool for interaction between economic and environmental fields [Khalil (2000)]. However, dynamical models are more useful as these consider temporal lags and nonlinearities; have strong interface for scenario testing [Agarwal, *et al.* (2002); Olabisi (2010)]; cover all the affecting forces [Yu, *et al.* (2011)] and consider feedbacks in a system [Veldkamp and Lambinb (2001)]. System dynamics methodology considers dynamic behaviour of the components in a system [Sterman (2000); Musango, *et al.* (2012)]. Computer based System Models are developed by constructing stocks and flows of information, material or data as sets of differential equations, linked through intermediary functions and data structures [Gilbert and Troitzsch (1999)]. Time is broken into discrete steps to allow feedback. Human and ecological interactions can be represented within these models, depending on the causes and functional representation [Baker (1989)].

System dynamics is a new approach in Pakistan for analysing wood consumption in the country. Using this methodology, the present study is designed to address the question: What is the sustainable wood supply gap (consumption minus sustainable production) in Pakistan? The main aim of this study is to build a system model for the forestry sector that covers wood products; timber and firewood; wood stock availability;

forest area; sources of wood supply; population growth and consumption of wood. The objective of the study is to discuss the changing trends of timber and fuel wood supply from State forests, farmlands and from imports. It also aims at discussing the use of wood for household, for industries and for commercial sectors. The gap between wood consumption and wood supply for Pakistan would be estimated over time. A policy option of doubling the growth of wood supply from farmlands would be considered to check wood consumption and sustainable wood supply gap.

This model would be a reference model for estimating and projecting wood resources in a country, using Pakistan as a case study. The contribution of the present study is the development of a methodology which may be helpful in conducting research around natural resource extraction, when there are data gaps.

II. FOREST AREA AND DEFORESTATION IN PAKISTAN

Humanity's Ecological Footprint is spread across six land use categories: cropland, grazing land, fishing grounds, built-up area, land for carbon absorption and forests [Kitzes, *et al.* (2007)]. The global forest area is approximately 4 billion hectares; about 7 percent of this is planted forests [FAO (2014a)]. Pakistan has 4.5 million ha. forest area (5.1 percent of the land area). The per capita forest area of 0.03 hectares is well below the world's average of 1 hectare [Bukhari, Haider and Laeeq (2012); PFI (2004)], and this amount is further decreasing with the growth of population. According to EUAD (1992), deforestation was 0.2 percent (7,000 to 9,000 ha per annum) in the 1980s. Conifer forests have been declining at the rate of 1.27 percent per annum since 1992 [Pakistan (1992); Ahmad, *et al.* (2012)]. The FAO (2009a) reported deforestation of 39,000 ha per year in the 1990s in Pakistan. According to FBS (2010), Pakistan's annual deforestation rate in 1999-2000 was between 1.8 percent, and was 2.1 percent during 2000-2005. Studies support the argument that deforestation in the Himalayan region is caused by increasing the human population [Eckholm (1975, 1976); Sterling (1976); Lall and Moddie (1981); Myers (1986)]. The IUCN (2002) has estimated that with the on-going rate of population growth, wood consumption in Pakistan would increase by 3 percent per year. Some studies indicate that rural fuel wood requirements do not seem to be a major cause of deforestation in designated forest lands in Pakistan [Ravindranath and Hall (1995)] while some other studies show that one of the main reasons for deforestation is timber and firewood harvesting in the country [FAO (1997c); Sheikh and Hafeez (1977); Knudsen (1995); Ali (1999)]. In the Western Himalayan region, in the Northern Areas (NAs) of Pakistan fuel wood consumption by local people is one of the causes of deforestation [Ali and Benjaminsen (2004)]. However, in forest-rich Northern Areas (NA) of Pakistan, population growth is slow. Ali and Benjaminsen (2004) attribute forest cutting in this region to the presence of timber smugglers [Yusufzai (1992)], who take the fallen wood and dead wood which was previously collected by locals as fuel wood, thus leaving the local people to harvest wood from public forests. In other words, commercial harvesting and corruption contribute to deforestation. The construction of the Karakorum Highway (KKH), linking Pakistan with China, is also contributing to deforestation [Schickhoff (1995); Ali and Benjaminsen (2004)]. Some studies are showing population growth as the prime threat to forests [Lodha (1991); Patil (1992); Dijk and Maliha (1994); Ahmad (1994). IUCN (1998); Payr (1999)] while others argue that blaming population growth is sometimes considered an over simplification of the complex problem of resource management. Other factors, like government policy on infrastructure development, including the forest clearance for other land use and increasing cash crop production are important causes [Nazir (2009); Ali (2004); Ali, *et al.* (2006); Wannitikul (2005); Write and Muller (2006); White and Dean (2004); Burgi, *et al.* (2000)].

Wood availability in Pakistan is highly dependent on forest wood stock and forest area. Table 1 gives an overview of forest areas in different parts of the country, with percentage contribution to the total national forests and percentage contribution to the land area.

Table 1

Forest Areas in Pakistan

Region	Khyber Pakhtunkhwa	Sindh	Punjab	FATA/ F R	Balochistan	AJK	Gilgit/ Baltistan	Islamabad	Total
Forest Area (m ha.)	1.51	0.661	0.554	0.534	0.499	0.435	0.337	0.0203	4.5
Percent of National Forest Area	33	14.5	12	11.75	10.8	10	7.5	0.45	100
Percent of Total Land Area in Forest	20.3	4.6	2.7	19.5	1.4	36.9	4.8	22.6	5.1

Source: Calculation based on data taken from Land Cover Atlas of Pakistan. PFI. 2012.

Table 2 gives the areas of State and farm forests in Pakistan. About 80 percent of the forest area is state owned forests while 18 percent is occupied by farmlands.

Table 2

Forest Area in Pakistan

Forest Area Category	Area (m hectares)
(1) Forests	3.44 (79.3% of the total forest area)
(2) Farmlands and Private Forests	0.781 (17.99% of total forest area)
(3) Others	0.119
Total	4.34 (5.01% of the land area)

Source: FAO (2009a).

III. WOOD CONSUMPTION AND WOOD SUPPLY IN PAKISTAN

Wood supplies about 30 percent of the total energy consumption in the Regional Wood Development Programme (RWEDP) in Asian member countries, which include Pakistan. In these countries, the consumption of wood is still increasing in absolute terms, even while the share of wood in national energy consumption is decreasing. Almost all countries in South and Southeast Asia are major fuel wood consumers and fuel wood producers. The total value of fuel wood is about US$ 30 billion per annum for the RWEDP countries together and some 2/3 of all fuel wood originates from non-forest land [FAO (1997a)].

The FAO (2009a) estimated that 72 percent of all wood used in Pakistan is consumed as fuel wood. The "fuel wood gap theory", formulated in the 1970s, posited that fuel wood is harvested primarily from state forests where growth rates are less than harvest rates, thus causing deforestation [FAO (1997c, 2009b, 2010)]. This gap in the past was being used by policy makers as justification for investment in forests. But current data indicates that about 60 percent of the global fuel wood is coming from non-forest areas and these sources are enough to bridge the gap between production and consumption [FAO (1997c)]. In Pakistan in 1991, out of a total of 29.4 million tons of wood consumed, 12.6 percent was from state owned forests and 84.1 percent from other lands, while 3.3 percent was from unknown sources [FAO (1997b)]. Driving forces of fuel wood consumption are household size; urbanisation and income level; and non-availability of alternate energy sources. In Pakistan, households that have a size of 16 or higher consume 2.17 times more than household with fewer than 5 persons [Ouerghi (1993)].

Pakistan's consumption of fuel wood was estimated at 26 million m^3 in 1992, increasing to 31.52 million m^3 in 2003. The consumption of fuel wood in the commercial sector was estimated at 1.047 million m^3 [FAO (2009a)]. The household sector is the largest consumer of wood with 79 percent to 81.8 percent [Hafeez (2000); Siddiqui (2000)], followed by the industrial sector at 14.9 percent and the commercial sector at 3.3 percent. The annual wood consumption in Pakistan was estimated 43.761 million cubic meters in 2003 compared to the annual forest growth of 14.4 million cubic meters, estimated in Forestry Sector Master Plan 1992. So, there is a gap of 29.361 million cubic meters per annum between production and consumption [UNDP-PK-ECC (undated); Pakistan (2005)]. Consumption of fuel wood is highly price-inelastic in Pakistan [Burney and Akhtar (1990)].

Mathtech (1988) used per capita (0.04 m^3) annual fuel wood requirement and estimated fuel wood consumption at 56 m^3 per year per person for 2008. An area equal to 2.8 million hectares would be required to provide that volume of fuel wood for the population. This may lead to a conversion of 14 percent of cultivated area to wood plantations. Sheikh (1990) also used per capita wood consumption and estimated 30 million m^3 total consumption for the year 2000. Both studies assumed constant population growth rate and constant per capita consumption. Similarly, consumption values are used to estimate timber supply from private lands. The volume of wood supplied by private lands is generated by subtracting the state and import supply from the total consumption [Amjad and Khan (1988); Sheikh (1990); Clark (1990)].

There are three sources of wood supply in Pakistan: State forests, private farmlands and imports. State controlled forests supply only 10 percent of the fuel wood and farmlands are estimated to produce 50 percent of the timber and 90 percent of the firewood used in the country. Timber and firewood production from State forests was 0.371 million m^3 and 0.32 million m^3 respectively in 1992, declining to 63 percent and 80 percent in 2009-10. This decline was mainly attributed to the wood harvesting ban implemented in 1993 [Fischer (2010)]. Amjad and Khan (1988) estimated the farm timber availability by taking estimated per capita timber consumption of 0.0239 m^3 per capita and multiplying it by the population to arrive at national consumption. This total consumption is then subtracted from public sector production and imports. Assuming the fixed household consumption rate, the figure for timber supplied from farmlands may be 1.2 million m^3 per year. This is 51 percent of the total timber production.

During 1990's, Pakistan's North-West Frontier Province (presently called Khyber Pakhtunkhwa) was leading in timber production with 49 percent, followed by Azad

Kashmir 20 percent, Sindh 15 percent, Punjab 11 percent and Northern Areas 5 percent. Fuel wood was coming from Punjab at 53 percent, Sindh 34 percent, NWFP (present KP) 8 percent, Northern Areas 3 percent and Balochistan 2 percent and with negligible production from Kashmir [Clark (1990)].

Imports were supplying about 36 percent of the total wood used in Pakistan during the 1990's. Malaysia is the main supplier of wood to Pakistan. Imports of wood have decreased in volume, as prices have increased [Clark (1990)]. Out of the total imports, about 10 percent of the volume and 6 percent of the value is timber wood. About 91 percent of the value is pulp, paper and paperboard; the import of which has increased since 1975 [Amjad and Khan (1988)]. The imports of wood in monetary terms increased during 1992–2003 (Table 5), at an average annual increase of 0.95 percent. They accounted for 1.92 percent of the total imports of the country. Exports have shown an increasing trend from1992-1993 to 2002-2003 with a per annum average growth rate of 1.78 percent. Out of the total exports, sports goods exports make up 92 percent, followed by furniture at 4.8 percent [FAO (2009a); UNDP-PK-ECC (2010)].

According to the Wood Supply and Demand Survey, the consumption of wood in Pakistan is expected to increase to 58 million m^3 by the year 2018. The wood shortage of 29.361 million m^3 assumes a constant forest growth of 14.4 million m^3 from state forests since 1992 [UNDP- PK-ECC (2010)]. The level of sustainable supply is below the actual consumption. The difference between the sustainable supply and the level of consumption would be considered as the annual depletion rate. It is therefore crucial to carry out an in-depth analysis of wood consumption and the sustainable production of wood, as well as the dynamics of these processes [Ouerghi (1993)].

IV. SYSTEMS DYNAMIC METHODOLOGY FOR ESTIMATING WOOD SUPPLY AND WOOD CONSUMPTION

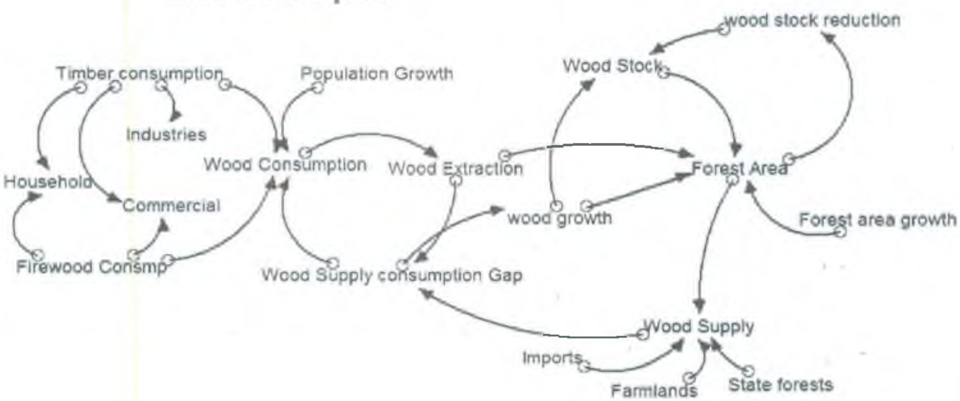
To develop systems' methodology, a procedure has been followed: first, by developing a conceptual model (section a); designing Stella built model (section b) and the model validation (section c). After that, the results have been described with discussion and policy implications.

A conceptual diagram (Fig. 1) has been built to show the relationship among variables. These variables are: wood consumption and driving forces of wood consumption; wood supply and sources of wood supply and wood supply consumption gap. Based on Fig. (1), a Systems Model (Fig. 2) has been developed by taking key stocks and flows, namely: forest area, wood stock and population growth. The model is structured by designing five frames, Population; Wood yield; Forest area; sources of wood supply and Wood consumption to show interlinkages among the variables. After model development, the model validation is done. Validation is a process of building confidence in the usefulness of a model [Forrester and Senge (1980)]. Forrester (1968) mentioned that one cannot expect absolute validity of a model but should remember that models are developed for a purpose. He further emphasised that the model can be valid for the purpose for which it has been designed but may not be valid for some other purposes. Therefore, models may not be proved valid but may be judged as valid [Barlas and Carpenter (1990)]. The features of model validation contain its "structure" and its "behaviour" [Lane (1998); Barlas (1996); Forrester and Senge (1980)]. Barlas (1989) highlighted some tests for validating systems' model behaviour, including comparing the trend and comparing the periods. The present study is based on trend analysis by taking past and projected periods. Two key variables, the population growth and wood consumption have been selected for our model validation. There are two reasons to select these variables, first, the problem of historic and projected data availability from official sources for rest of the variables and second, these two variables have given information and help to estimate model data on other variables, for example, wood supply from different sources (see section e. frame five). Therefore, if the source variable (wood consumption) and key driving force variable (population growth) is validated, the rest of the results would be confidently used for projection.

(a) Model Description

The conceptual diagram is as follows (Fig.1):

Fig. 1. A Conceptual Diagram showing Forest Wood Stock and Forest Wood Consumption



The diagram above (Fig. 1) shows the relationship and effect of the systems' components. Starting with the initial variable, wood consumption, affected by population growth leads to more wood extraction from the forests, as a result, the wood supply-consumption gap increases, unless brought about high forest growth and more area under forestation, which in the present case, is deficient. Consumption of wood that is increased because of population growth may thus be higher than wood supply. In other words, it reveals the fact that wood consumption is accelerating supply consumption gap. On the other hand, reduction in forest area through deforestation leads to greater pressure on wood stock, thus in turn putting more pressure on forest area. One balancing factor that reduces the wood supply consumption gap is the growth of the forest area. The higher the level of forest area growth, the more the forest land cover is, thus signalling that wood supply can compensate enhanced wood consumption.

(b) Computer Simulation Model

The following computer simulation model (Fig. 2) is built by using software "Stella" (version 10.1). First, the scattered information is compiled on wood supply and wood consumption (frame five), then converting these statement's based information into formulas (model equations in Appendix) to develop time series data (model data in appendix). The time period for simulation is considered 40 years between 1990 and 2040, i.e. projecting outcomes for twenty years on the basis of the past twenty years' change in selected variables. The stocks, flows and auxiliary variables are presented in Fig. (2). The model is divided into five frames. The explanation and calculation procedure used under each frame is described as follows:

(a) Frame one representing *"Forest area"*. Forest area growth, determined with the help of Stella based sensitivity analysis, is found at the growth rate 1.1 percent. At this growth level, the forest area as calculated by the model is consistent with the national data on forest area.

(b) Frame two is displaying *"Wood Yield"*. The forest wood stock contains wood from the state owned forests and from farmlands. By combining data from Forest Department working plans, the farmland tree survey and the Household Energy Strategy Study (HESS), the Forestry Sector Master Plan mentioned a total national standing volume of wood as 368 million cubic meters in 1992 (Table 3). This data has been incorporated in our model to calculate wood supply.

Table 3

Forest Wood Stock and Yield

Year	1992
Farmland Standing Stock (mm^3)	70.3
Farmland Stock Growth per Annum (mm^3)	7.7
Total National Standing Stock (including Farmland) (mm^3)	368
Total National Wood Yield Per Annum (mm^3)	40.112

Source: Calculated on the basis of data taken from EC-FAO (Dec. 2002), wood yield per annum has been converted to mm^3 on the basis of 22.2 m tones which is declared as 10.9 percent of the total standing stock.

(c) Frame three is highlighting *"People"* i.e. population growth. The present study takes into account the annual growth in population and per capita wood consumption. Some other studies also considered constant population growth and constant per capita wood consumption [Mathtech (1988); Amjad and Khan (1988); Sheikh (1990)]. Population of the country stands at 112 million for the year 1990, with average birth rate 25.4 per thousand and average death rate 7.43 per thousand [FBS (2002)]. Population is an accelerating variable for wood consumption in the country. Per capita firewood (0.2017) and per capita timber (0.046) consumption have been calculated to use it in the Stella model. Wood consumption driven by population growth is projected to the year 2040.

(d) Frame four is portraying *"Sources of wood consumption"*. Total wood consumption includes timber consumption and firewood consumption. Since time series data on timber consumption is not available, the value of firewood consumption in 1990 taken from FBS (2010) is subtracted from the total wood consumption to get timber consumption. The figures for timber and firewood consumption for years 2010-11 have been taken from Zaman and Ahmad

(2012). Based on the 1990 and 2010 figures, the time series data has been obtained for both timber and firewood consumption by using the following formula:

Rate of Change per year R= (f/s)^(1/y) - 1
Where f= final year value, s= start year value and
Y= end year to first year= 21-1=20 Thus R*100= Percentage change over the said period

(e) Frame five is displaying "*Wood Supply Sources*". Sources of wood supply are taken as wood from state forests, from farmlands and from imports. The wood supply from these sources is derived out of their share in the total wood consumption, as total national wood supply figures with respect to each source are not available. Following information, retrieved from the literature,[1] is summarised below and then converted into equations to incorporate into the Stella model:[2]

Out of the total firewood consumption, from 1990 till 1996, 10 percent of the firewood consumption was supplied by State forests. After 1996, the figure dropped to 0.91 percent because the share of farmland increased. Of the total timber consumption, from 1990 to 1995, timber consumption from state forests was 18 percent, in 1996 it became 10 percent, from 1997 and onward it was 8 percent. From 1990 to 1995 timber supply from farmlands was 41 percent, from 1996, it became 63 percent and from 1997 onward it was 72 percent of the total timber consumption. Out of the total firewood consumption, from 1990 till 1996, 90 percent of the fuel wood was supplied by farmlands and the remaining 10 percent by State forests. After 1996, the ratio changed to 99.09 percent and 0.91 percent respectively. The household sector uses 81 percent of the firewood consumption, industrial fuel wood entrepreneurs use 14.9 percent of the firewood consumption and the commercial sector consumes 3.3 percent of the firewood [FAO (2009a)]. Imports were initially 41 percent of the total timber consumption, later decreasing to 20 percent in the 2000's and then to 5 percent during 2005-2010 [FAO (2009); UNDP-ECC (2010); Clark (1990); and Pakistan (2005)].

Combining the information described in the above five frames, total wood supply; total wood consumption; supply consumption gap; total wood extraction from forests; State owned forests and farmlands; per hectare yield extraction and wood stock availability are estimated over time from 1990 to 2010 and projected to 2040. The study considers the impact of potential policy option of enhancing wood growth from farmlands on wood consumption and sustainable wood supply gap.

The abbreviated variables in the model Fig. (2) and in equations (Appendix) are explained as:

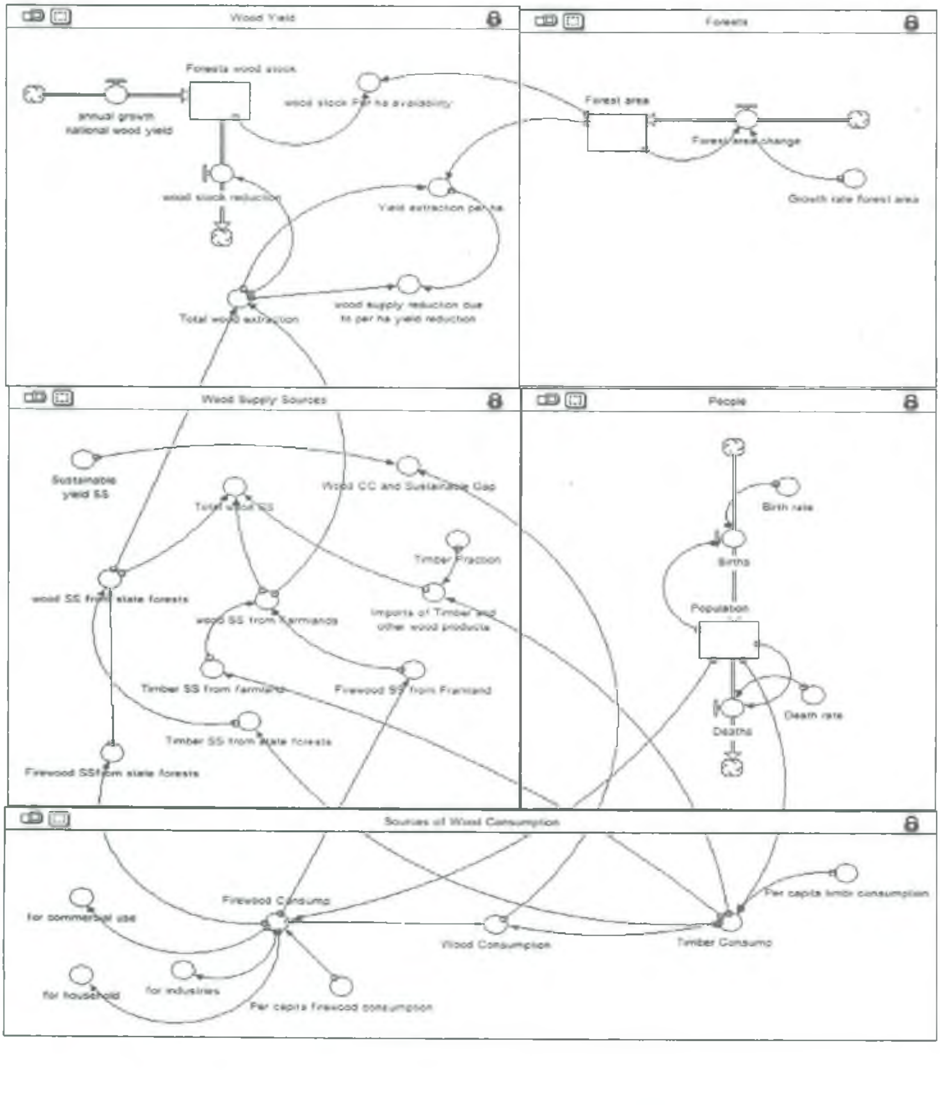
The variables; "INIT Forest area", "INIT Population" and "INIT Forest wood stock", are the initial values (values for the starting year 1990) for forest area, population and forest wood stock, respectively. "Sustainable Yield SS" represents sustainable yield supply of wood. Similarly, "Total Wood SS" stands for total

[1]Percentage share of wood supply from each sector is calculated by taking data from FAO (2009), UNDP-ECC (2010), Clark (1990) and Pakistan (2005)

[2]See model equations on wood consumption and wood supply

wood supply. "Wood SS from state forests" and "Wood SS from Farmlands" represent data on wood supply from State Forests and from Farmlands. "Wood CC and Sustainable Gap" stands for gap between wood consumption and sustainable wood production. "Timber Fraction" is the percentage share of imported wood in the total wood consumption with respect to time. "Timber SS from State Forests" and Timber SS from Farmlands" represent variables for timber supply from State Forests and from Farmlands, respectively. Similarly, "Firewood SS from State Forests" and Firewood SS from Farmlands" represent data on firewood supply from State Forests and from Farmlands, respectively. Three other variables; "for industries", "for household" and 'for commercial use" display data on firewood consumption for these three areas.

Fig. 2. Systems Model Showing Sources of Wood Supply and Forest Wood Consumption in the Country



(c) Model Validation

The model was validated by comparing model projections of population and wood consumption. For the data on population, the model is validated in the light of information taken from FBS (2010) and from Zaman and Ahmad (2012). For wood consumption, the projected data is taken from Zaman and Ahmad (2012). The model data is found almost consistent with population. The model is however projecting lower wood consumption (52 million m^3) in 2025, compared to other sources (59 million m^3) for the same year (Figure 3 a, b). The data is presented in Table (4) in appendix.

Fig. 3 (a) Model Validation: Historic Trends and Projection for Wood Consumption

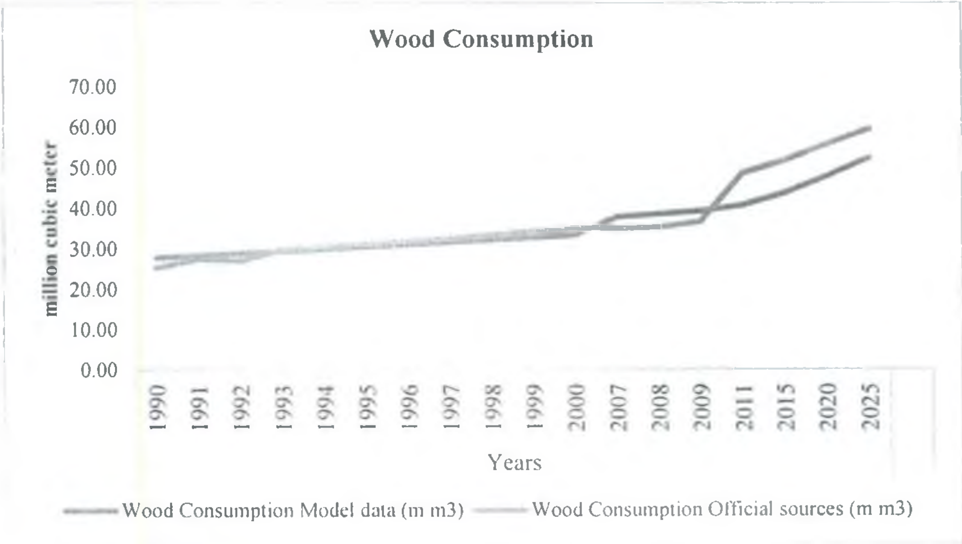
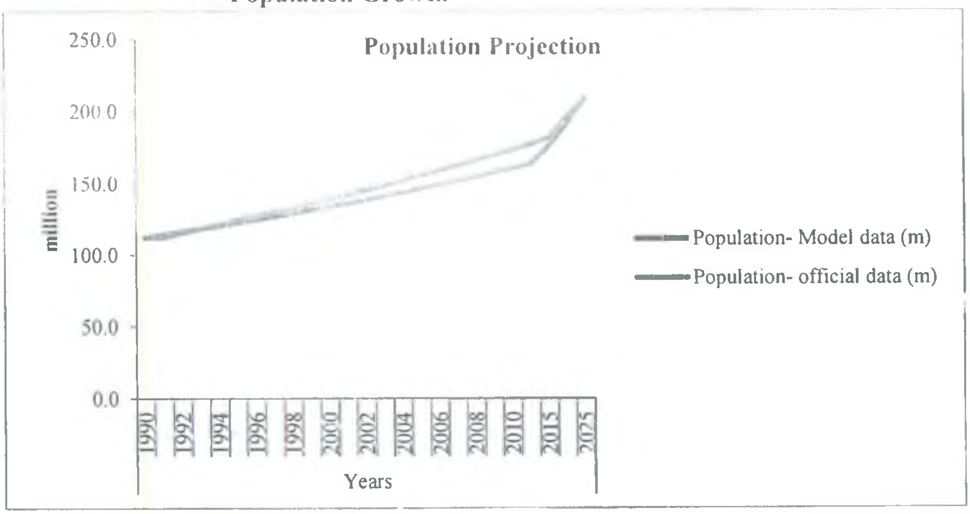


Fig. 3(b) Model Validation: Historic Trends and Projection for Population Growth



V. RESULTS

The results of the model are presented below. Detailed model output is given in Table 5 (Appendix):

Forest Area and Wood Stock

Forest area is projected to increase from 3.46 million hectares in 1990 to 5.98 million hectares in 2040. The model results show that total wood stock of 368 million m^3 in 1990 is projected to reduce to 232 million m^3 in 2040. The national wood growth of 40.112 million m^3 per annum has been added to the wood stock. However, total wood stock has decreased over time because of the increasing pressure of wood extraction from the forests.

Wood Supply and Sources of Wood Supply

The model results show that in 1990, firewood supply from State forests and farmlands was 2.3 million m^3 and 20.4 mm^3 respectively. Timber supply from State forests, farmlands and imports were 0.9 mm^3, 2.1 mm^3 and 2.1 mm^3 respectively. Total wood supply in 1990 from State forests, farmlands and imports was 3.2 mm^3, 22.5 mm^3 and 2.1 mm^3 (Fig. 4, 5 and 6). For 2040, the projection of firewood supply from State forests and farmlands is 0.5 mm^3 and 54.9 mm^3. In 2040, the timber supply from State forests, farmlands and imports would be 1.0 mm^3, 9.2 mm^3 and 0.6 mm^3 respectively. Total wood supply from farmlands would increase from 22.5 mm^3 in 1990 to 64.1 mm^3 in 2040, whereas wood availability from state forests would decrease from 3.2 mm^3 in 1990 to 1.5 mm^3 in 2040.

Fig. 4. Wood Supply from State Owned Forests and from Imports

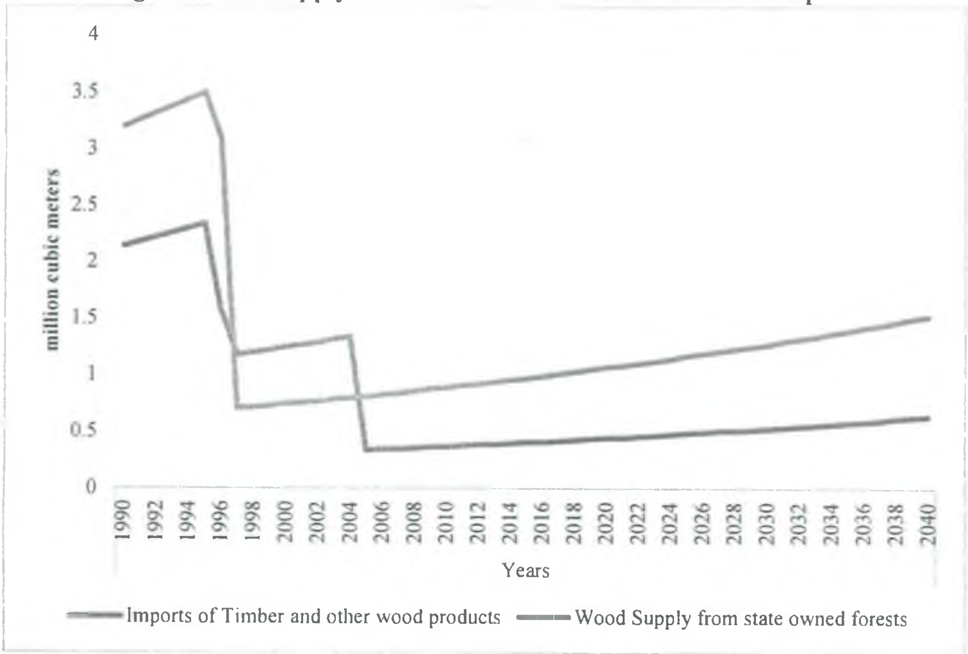


Fig. 5. Supply of Wood from Farmlands

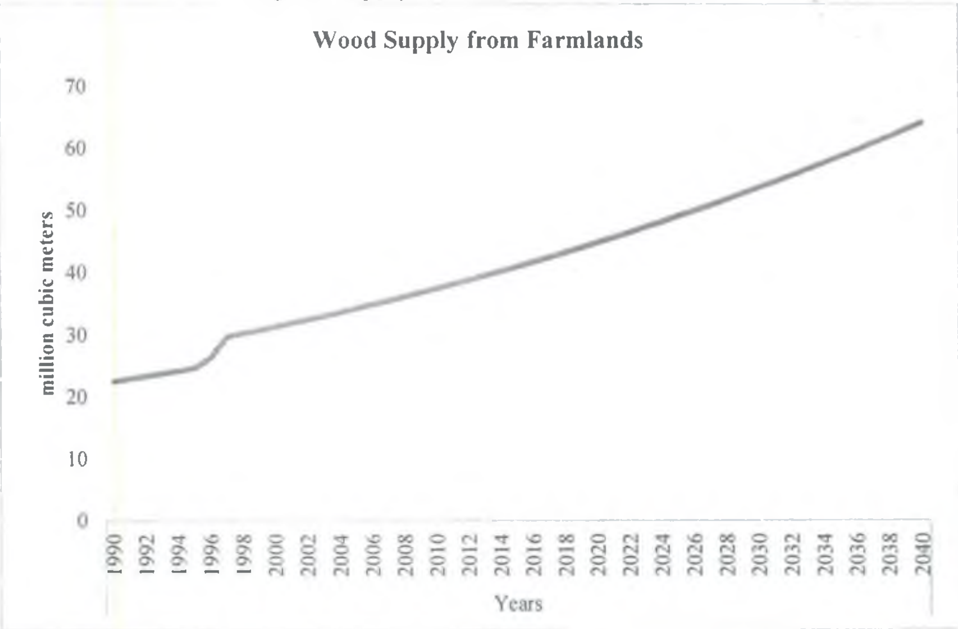
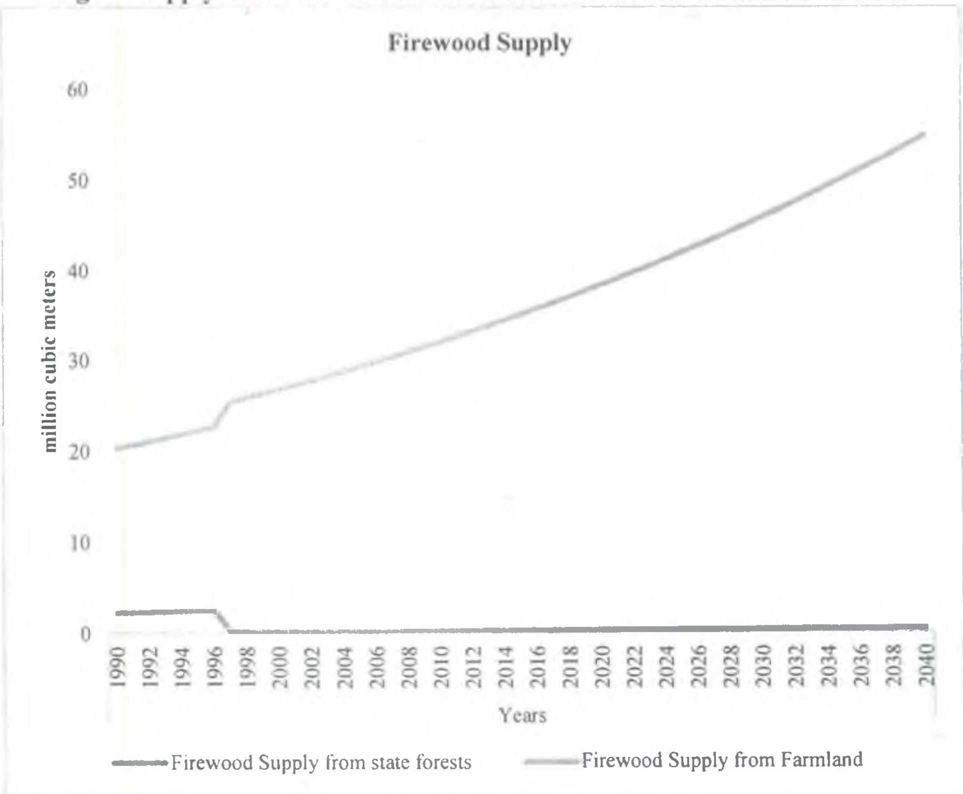


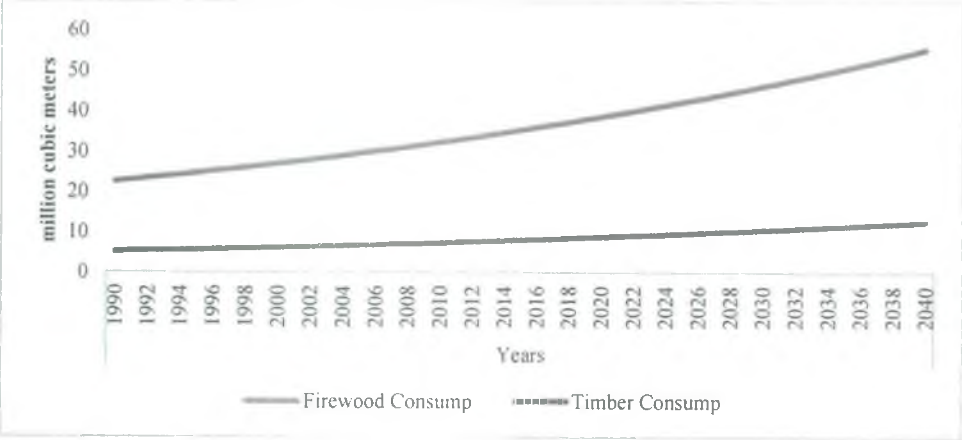
Fig. 6. Supply of Firewood from State Owned Forests and from Farmlands



Wood Consumption Trends

The model results show that in 1990, the consumption of firewood and timber was 22.7 mm³ and 5.2 mm³, respectively. The firewood and timber consumption in 2040 would reach to 55.7 mm³ and 12.8 mm³, respectively (Fig. 7). The total wood consumption was about 27.9 mm³ in 1990 and is projected to reach about 68.6 mm³ in 2040. As the population is growing, the firewood use for households would increase over time from 18.3 mm³ in 1990 to 44.8 mm³ in 2040. For commercial use and for the industrial sector, firewood consumption would increase from 0.75 and 3.4 million m³ in 1990 to 1.84 and 8.3 million m³ in 2040, respectively.

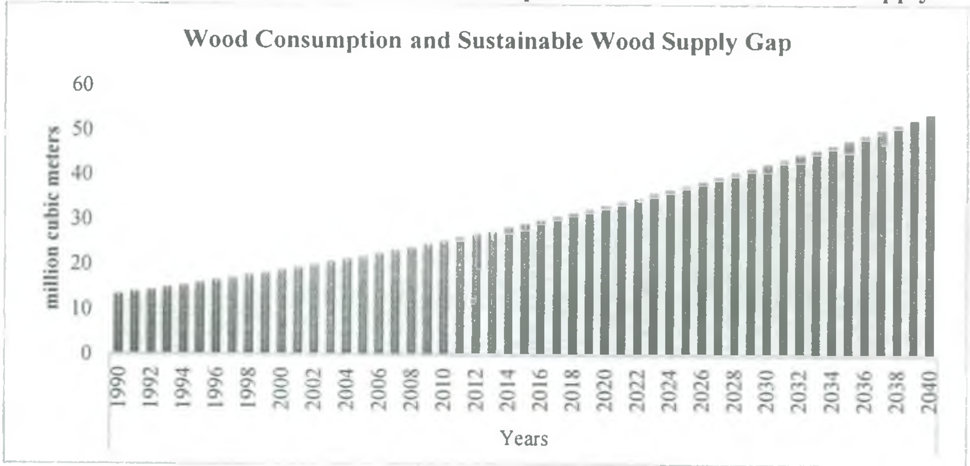
Fig. 7. Firewood and Timber Consumption



Sustainable Wood Supply and Wood Consumption

Based on the sustainable wood supply of 14.4 million m³, as estimated in forestry sector Master Plan 1992, and time series data on wood consumption, developed by the present model, the gap between sustainable wood supply and wood consumption is estimated at 13.5 million m³ in 1990, projecting to 53.8 million m³ in 2040 (Fig. 8).

Fig. 8. Gap Between Total Wood Consumption and Sustainable Wood Supply



Effect of Policy Intervention

Under the present situation of energy crisis in Pakistan, consumption of wood products should not be ignored, for the population is also increasing. During financial year 2014-15, out of the total electricity generation in the country, 36.80 percent was from oil, 26.5 percent from gas, 30.40 percent from hydel, 5.4 percent from nuclear and 0.7 percent from coal [HDIP (2015)]. Electricity generation in Pakistan is dominated by thermal power plants (68 percent), running on imported oil [NEPRA (2013)]. According to State Bank of Pakistan, we imported approximately $12 b., worth of oil during 2014-15, which was 30 percent of the total import bill [PBC (2016)]. The projection shows that by 2022, total electricity production would be 53404 MW and the share of renewable sources would be only 9 percent of the total electricity production. Total demand is projected to increase at 72169 MW by 2025. About 51 Million people in the country have no access to electricity. Based on technical and economic feasibility, around 32,889 villages cannot be connected to the national grid [Khan (2016)]. Thus, it is imperative not to ignore the use of wood consumption in the country. Therefore, the sustainable wood supply should be considered. There is a need to increase sustainable wood supply.

For improving sustainable yield from the forest, in our model, we are left with two viable options: increase in forest area and increase in farmland wood growth to reduce the wood consumption-supply gap. To test this strategy, the growth of wood from farmlands was enhanced in the model to double of its present level i.e. 7.7 million cubic meters, thus the gap between wood consumption and sustainable supply would be decreased from 53.8 million m^3 per year to 46 million m^3. This quantity is still substantial, thus leading us to think that enhancing growth of wood from farmland will not be effective unless forest area would be increased through afforestation.

VI. DISCUSSION, CONCLUSION AND IMPLICATION OF THE STUDY

Wood supply and consumption in a country depends on several factors, forest area; wood stock availability; domestic and foreign sources of wood supply and above all population growth. With growing population and shortage of electricity and gas in Pakistan, consumption of wood especially fuel wood has increased over time. There are three sources of wood supply: state owned forests, farmlands and imports. During 1990-2010, the share of state owned forest in total wood supply decreased from 11.5 percent to 2.3 percent, whereas the share of farmlands in total wood supply increased from 80.8 percent to 96.7 percent during the same period. The imports of wood have decreased over time, thus putting more pressure on domestic forests; both state owned forests and farmlands. The wood extraction from domestic forests increased over time; the pressure is more for firewood than timber. Out of the total wood consumption, the share of firewood consumption was 81.3 percent whereas the share of timber was 18.7 percent. For firewood, the state-owned forests contributed 10 percent while the contribution of farmlands remained 90 percent in the total firewood supply. With the passage of time the share of state owned forests in firewood supply further decreased to less than 1 percent while the share of farmlands increased to 99.1 percent. The demand for firewood is highest from the household sector, followed by the industrial sector and commercial use. Other studies are highlighting that the main use of wood in forest rich areas especially in

Hazara and Swat by local people is for cooking, followed by wood use for construction and for fodder. Local population typically does not engage in large scale wood cutting for commercial purposes [Nazir (2009); Ali (2004); Ali, *et al.* (2006)].

Like fuel wood supply trends, timber supply from state forests has decreased from 18 percent to less than 10 percent while the share of farmlands has increased from about 41 percent to 84 percent, while wood extraction was increasing from domestic forests, created negative pressure on wood stock. Wood yield extraction per hectare would increase from 7.4 cubic meters in 1990 to 10.9 cubic meters in 2040, thus resulting in a decline in wood stock availability over time. It is estimated that wood extraction from domestic forests will surpass annual national wood yield growth (40.112 million m^3) in 2018. Sustainable supply of wood is estimated at 14.4 million m^3 annually in Pakistan [Pakistan (1992); UNDP-ECC (undated); Pakistan (2005)]. The results of the present study estimated that the gap between sustainable wood supply and wood consumption increased over time in the country, thus reaching the conclusion that unsustainable wood extraction from domestic forests increased from 11 million m^3 in 1990 to 51 million m^3 in 2040.

The research on forestry issues in Pakistan shows that a large part of the population depends on wood, as fuel source and for construction [Ali, Tanvir, and Suleri (2006)]. Since the alternate energy sources are either not available to large part of the population or are expensive, main stress is on wood sources. This is also aggravating illegal cutting and timber smuggling from national forests in Pakistan [UNOCD and SDPI (2011)]. Further, studies show that the insufficient data availability is a hindrance in the way of forest product analysis [see for example, Ouerghi (1993); Khalil (2000)]. The present study is designed with the aim to estimate data on key forestry variables under the assumption that, in the absence of sufficient alternate energy supply, if the present rate of wood consumption is continued, there would be high demand in future, as the population is increasing, thus increasing consumption and the supply gap. Other studies are also projecting high wood consumption in the country [see for example, UNDP- PK-ECC (undated)]. Fisher, *et al.* (2010) also mentioned that the demand supply gap may increase to 13.6 million m^3 by 2050. High demand supply gap may result in depleting and disappearance of forest areas of Malakund and Hazara by 2027 [Joachim (2000)]. Siddiqui and Amjad (1993) also mentioned that the reliance on wood is expected to remain high in Pakistan in the foreseeable future. Since land conversion is also going on. There is a need to take substantial steps to meet the needs of the local communities. Nazir and Ahmad (2016) estimated long term land use conversion trends in Pakistan and found that if the present rate of land conversion would not be checked, an area equal to 0.0536 m. ha would be converted to construction area, rangeland area and agriculture land by 2030. Controlling deforestation is not the only strategy, as estimated by Nazir and Ahmad (2016) but efforts should be made to increase sustainable wood supply and to provide alternative energy sources in the country. The area under forest has also been estimated in the present study. The forest area of Pakistan is low by international standards. Forest area is projected to increase only to 5.4 million hectares in 2040 from 3.4 million hectares in 1990. The growth seems to be very slow because of high deforestation in Pakistan and low rate of afforestation and regeneration. Velle (1998) mentioned that in 1998, normal regeneration was observed only in 5.5 percent of the forest area, some regeneration in 24 percent of the area, while no regeneration was observed in 70.5 percent of the area. At global level, programmes have been launched to increase forest area by planting billion trees [UNEP (2011)]. The present KP government has also taken an initiative under its programme "Billion Tree Tsunami Afforestation Project" (BTTAP), to plant one billion trees to meet the demand of wood for the local communities and to increase forest area to 2 percent [Govt. of KP (2015)]. This project emphasised the participation of local communities and plantation on farmlands. The present study suggested that increasing wood supply from farmlands might ease some pressure on forests but would still not solve the problem totally. Rauf (1994) also emphasised the need of agro-forestry to meet Pakistan's fuel wood needs. Ayaz and Wani (2000) mentioned that the major contributors in the national wood supply were farmlands. The prospects of farm forestry are evident in the HESS wood demand survey, which indicated that during 1990-91 around 125 million trees were planted and the share of non-fruit trees was almost 90 percent. The largest proportion of the planted trees (44.9 percent) was for timber, where 29.8 percent was destined for fuel purposes, with the remainder being planted for fruits, shade, fodder and other purposes [Ouerghi (1993)].

For the proper management of forests in a country, it is necessary to estimate the present and projected forest resources. The consumption and supply of wood resources is one of the main areas that needs proper planning. Methodology that incorporates systems' components and its changing trends, to estimate natural resource variables, gives us a detailed picture of a problem. System dynamics methodology also helps to generate data for variables for which there is insufficient information available. Pakistan's forestry sector also suffers from data deficiency. The present case study of building a systems' model by developing causal relations and feedback loops of data with information gaps helped us to develop time series data of wood supply and consumption in Pakistan. Research based on case studies help to replicate the model for other similar settings.

In developing countries, the underlying driving force for wood consumption is population growth. The growing population in Pakistan is resulting in an increasing demand for forest products. The main area of concern is firewood use; particularly by households. There is a limited room for growth in wood supply from State forests as there is no significant increase in forest area. Imports of wood, being expensive, are declining. It is pertinent to focus on increasing sustainable wood by focusing on farmland growth and afforestation in the country.

Model estimated data on key variables, such as: national wood stock; timber supply from farmlands and from state forests (mm^3); firewood supply from farmlands and from state forests (mm^3); imports of wood products (mm^3) and projected wood supply consumption gap, is a valuable addition to the literature of forestry of Pakistan. The results of the study can be used to estimate other variables and address other issues in the field. For example, the targets set under Billion Tree Tsunami Project and projected change after the inclusion of the project in the existing growth is to calculate sustainable wood availability in the country and estimating change in the volume of wood stock and wood consumption etc. By using demand supply gap, this study would be helpful in estimating the illegal wood harvest in the country.

APPENDIX

Model Equations and Supporting Data

Variables	Data and Equations
Forest area (t)	Forest area (t - dt) + (Forest area change) * dt
INIT Forest area	3460000 hectares
INIT Forests wood stock	368000000 m^3
Growth rate forest area	1.1%
INIT Population	112270000
Birth rate	25.45
Death rate	7.4
Annual growth national wood yield	40112000
Sustainable yield SS	14400000
Per capita firewood consumption	0.201754698 m^3
Average Per capita timber consumption	0.046429402 m^3
Firewood Consumption	Per capita firewood consumption*Population
Firewood from Farmland	IF TIME<=1996THEN.90*Firewood Consumption ELSE 0.9909*Firewood Consumption
Firewood from state forests	If time < = 1996 then 0 .1 *Firewoo Consumption else 0.0091* Firewood Consumption
Firewood for commercial use	0.033*Firewood Consumption
Firewood for household	0.81*Firewood Consumption
Firewood for industries	0.149*Firewood Consumption
Imports of Timber, other wood	Timber Consumption *Timber Fraction Timber Fraction
GRAPH (TIME)	Timber Fraction = 0.41 (1990-1995), 0. 27 (1996), 0. 20 (1997-2004), 0.05 (2005-10)
Supply from Farmlands	Firewood from Farmland +Timber from farmland
Timber from Farmland	IF TIME > = 1990 AND TIME <= 1995 then 0.41*Timber Consumption
ELSE	IF TIME =1996 then 0.63*Timber Consumption ELSE 0.72*Timber Consumption
Timber from State forests	IF TIME > = 1990 AND TIME <= 1995 then 0.18*Timber Consumption
ELSE	IF TIME = 1996 then 0.10*Timber Consumption ELSE 0.08*Timber consumption
Forests wood stock (t)	Forests wood stock (t - dt) + (annual growth national wood yield – wood stock reduction) * dt
Wood stock reduction	Total wood extraction
Total wood extraction	Wood SS from state forests + wood SS from Farmlands
Total wood SS	wood SS from state forests + Imports of Timber and other wood products + wood SS from Farmlands
Wood CC and Sustainable Gap	Wood Consumption-Sustainable yield SS
Wood stock per ha availability	Forests wood stock/Forest area
Yield extraction per ha	Total wood extraction/Forest area

Table 4

Model Validation for Wood Consumption and Population

Years	Model Data* Wood Consumption (million m^3)	Official Data Wood Consumption (million m^3)	Model Data* Population (m.)	Official Data Population (m.)
1990	27.86	25.38	112.3	112.27
1991	28.37	27.523	114.3	112.61
1992	28.89	27.08	116.4	115.54
1993	29.41	29.815	118.5	118.5
1994	29.94	30.53	120.6	121.48
1995	30.49	31.243	122.8	124.49
1996	31.04	31.955	125	127.51
1997	31.61	32.576	127.2	130.56
1998	32.18	33.425	129.5	132.25
1999	32.77	34.298	131.9	136.69
2000	33.36	35.192	134.3	139.96
2007	37.84	34.98	152.2	162.91
2008	38.53	35.274	154.9	166.41
2009	39.23	36.615	157.7	169.94
2011	40.67	48.52	163.5	177.1
2015	43.71	51.71	175.6	181.74
2020	47.83	55.64	192	195.49
2025	52.33	59.44	210	208.84

Source: Federal Bureau of Statistics (2011-12). Zaman and Ahmad (2012).

* Results of the model.

Table 5

Model Data Showing Wood Stock, Wood Supply and Wood Consumption in the Country (million m^3)

Years	Forests wood stock	Firewood Supply from state owned forests	Firewood Supply from Farmland	Imports of Timber & wood products	Timber Supply from farmland	Timber Supply from state owned forests	Wood Supply from Farmlands	Wood Supply from state owned forests	Total wood Supply	Fire wood Consumption	Timber Consumption	Wood Consumption
1990	368	2.27	20.39	2.14	2.14	0.94	22.52	3.2	27.86	22.65	5.21	27.86
1991	382.4	2.31	20.75	2.18	2.18	0.96	22.93	3.26	28.37	23.06	5.31	28.37
1992	396.3	2.35	21.13	2.22	2.22	0.97	23.34	3.32	28.88	23.48	5.4	28.88
1993	409.8	2.39	21.51	2.26	2.26	0.99	23.76	3.38	29.4	23.9	5.5	29.4
1994	422.7	2.43	21.9	2.3	2.3	1.01	24.19	3.44	29.93	24.33	5.6	29.93
1995	435.2	2.48	22.29	2.34	2.34	1.03	24.63	3.5	30.47	24.77	5.7	30.47
1996	447.2	2.52	22.7	1.57	3.66	0.58	26.35	3.1	31.02	25.22	5.8	31.02
1997	457.8	0.23	25.44	1.18	4.25	0.47	29.69	0.71	31.58	25.67	5.91	31.58
1998	467.5	0.24	25.9	1.2	4.33	0.48	30.23	0.72	32.15	26.14	6.01	32.15
1999	476.7	0.24	26.37	1.22	4.41	0.49	30.77	0.73	32.73	26.61	6.12	32.73
2000	485.3	0.25	26.84	1.25	4.49	0.5	31.33	0.75	33.32	27.09	6.23	33.32
2001	493.4	0.25	27.33	1.27	4.57	0.51	31.9	0.76	33.92	27.58	6.35	33.92
2002	500.8	0.26	27.82	1.29	4.65	0.52	32.47	0.77	34.54	28.07	6.46	34.54
2003	507.7	0.26	28.32	1.32	4.74	0.53	33.06	0.79	35.16	28.58	6.58	35.16
2004	514	0.26	28.83	1.34	4.82	0.54	33.65	0.8	35.79	29.1	6.7	35.79
2005	519.6	0.27	29.35	0.34	4.91	0.55	34.26	0.81	35.42	29.62	6.82	36.44
2006	524.6	0.27	29.88	0.35	5	0.56	34.88	0.83	36.06	30.16	6.94	37.1
2007	529	0.28	30.42	0.35	5.09	0.57	35.51	0.84	36.71	30.7	7.07	37.77
2008	532.8	0.28	30.97	0.36	5.18	0.58	36.15	0.86	37.37	31.26	7.19	38.45
2009	535.9	0.29	31.53	0.37	5.27	0.59	36.8	0.88	38.04	31.82	7.32	39.14
2010	538.3	0.29	32.1	0.37	5.37	0.6	37.47	0.89	38.73	32.39	7.45	39.85
2011	540.1	0.3	32.68	0.38	5.46	0.61	38.14	0.91	39.43	32.98	7.59	40.57
2012	541.2	0.31	33.27	0.39	5.56	0.62	38.83	0.92	40.14	33.57	7.73	41.3
2013	541.5	0.31	33.87	0.39	5.66	0.63	39.53	0.94	40.87	34.18	7.87	42.05
2014	541.2	0.32	34.48	0.4	5.77	0.64	40.25	0.96	41.6	34.8	8.01	42.81
2015	540.1	0.32	35.1	0.41	5.87	0.65	40.97	0.97	42.35	35.43	8.15	43.58
2016	538.2	0.33	35.74	0.41	5.98	0.66	41.71	0.99	43.12	36.06	8.3	44.36
2017	535.6	0.33	36.38	0.42	6.08	0.68	42.47	1.01	43.9	36.72	8.45	45.17
2018	532.3	0.34	37.04	0.43	6.19	0.69	43.23	1.03	44.69	37.38	8.6	45.98
2019	528.1	0.35	37.71	0.44	6.31	0.7	44.01	1.05	45.5	38.05	8.76	46.81
2020	523.2	0.35	38.39	0.45	6.42	0.71	44.81	1.07	46.32	38.74	8.92	47.66
2021	517.4	0.36	39.08	0.45	6.53	0.73	45.62	1.08	47.15	39.44	9.08	48.52
2022	510.8	0.37	39.79	0.46	6.65	0.74	46.44	1.1	48.01	40.15	9.24	49.39
2023	503.4	0.37	40.5	0.47	6.77	0.75	47.28	1.12	48.87	40.88	9.41	50.28
2024	495.1	0.38	41.24	0.48	6.9	0.77	48.13	1.14	49.75	41.61	9.58	51.19
2025	485.9	0.39	41.98	0.49	7.02	0.78	49	1.17	50.65	42.36	9.75	52.11
2026	475.9	0.39	42.74	0.5	7.15	0.79	49.88	1.19	51.57	43.13	9.93	53.05
2027	464.9	0.4	43.51	0.51	7.28	0.81	50.78	1.21	52.5	43.91	10.1	54.01
2028	453.1	0.41	44.29	0.51	7.41	0.82	51.7	1.23	53.44	44.7	10.29	54.99
2029	440.2	0.41	45.09	0.52	7.54	0.84	52.63	1.25	54.41	45.51	10.47	55.98
2030	426.5	0.42	45.91	0.53	7.68	0.85	53.58	1.27	55.39	46.33	10.66	56.99
2031	411.7	0.43	46.74	0.54	7.81	0.87	54.55	1.3	56.39	47.17	10.85	58.02
2032	396	0.44	47.58	0.55	7.96	0.88	55.54	1.32	57.41	48.02	11.05	59.07
2033	379.2	0.44	48.44	0.56	8.1	0.9	56.54	1.34	58.45	48.88	11.25	60.13
2034	361.5	0.45	49.31	0.57	8.25	0.92	57.56	1.37	59.5	49.77	11.45	61.22
2035	342.6	0.46	50.2	0.58	8.39	0.93	58.6	1.39	60.57	50.66	11.66	62.32
2036	322.8	0.47	51.11	0.59	8.55	0.95	59.65	1.42	61.67	51.58	11.87	63.45
2037	301.8	0.48	52.03	0.6	8.7	0.97	60.73	1.44	62.78	52.51	12.08	64.59
2038	279.7	0.49	52.97	0.62	8.86	0.98	61.83	1.47	63.91	53.46	12.3	65.76
2039	256.6	0.5	53.93	0.63	9.02	1	62.94	1.5	65.07	54.42	12.52	66.95
2040	232.2	0.5	54.9	0.64	9.18	1.02	64.08	1.52	66.24	55.4	12.75	68.15

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