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Illegal Logging and Wood Consumption: Estimation and Projection of Illegal Wood Harvesting in Pakistan through System Dynamics

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Abstract

The scale and impacts of the illegal logging economy are an important and interesting area of research, which suffers from data deficiency that makes the analysis a challenging task, especially in developing countries. The present study is an attempt to estimate the illegal wood harvest from State forests in Pakistan, using a system dynamics model to simulate time series data from 1990-2010. Projections of illegal logging were made up to 2029-30. Depending on the global estimation criteria for illegal logging, the study incorporated legal harvest from the State forests in a system dynamics model with population growth as a driving force of wood consumption. The supply contribution of State forests to total wood consumption and wood actually harvested from State forests is set as a base to estimate the level of illegal wood harvest. The monetary value of illegally harvested wood is determined on the basis of forestry sector contribution to GDP. The results show that illegal wood harvest is 4 times more than the legal wood harvest, and after the harvesting ban this ratio has decreased over time with the increasing share of wood supply from farmlands.

Keywords: illegal wood harvest, wood consumption, state forests, GDP, Pakistan.

1. Introduction

Illegal logging is a significant part of the black market. The illegal logging economy involves a set of actors that are complex and diverse both in nature and operation (Brown, 2011). Different definitions of illegal logging lead to different conclusions on the magnitude of the problem (Miller et al., 2006). Illegal logging usually refers to one or more of the following malpractices: logging of protected or endangered species, including those listed under the Convention on International Trade in Endangered Species (CITES); logging in protected areas; logging in violation of permits, violating rules related to size, area of logging and volume of logging, or other official requirements; logging with fake or illegally obtained permits; damaging trees to make them vulnerable to fell legally; processing timber without permits and documentation; practices to avoid taxation;

redefinition of forest classification; overvaluing and buying timber above market price (Brack, 2003; Brack et al., 2002; Callister, 1999; Nellemann, 2012; Contreras-Hermosilla, 2000; UNODC 2013). Illegal logging results in deforestation, deprives local communities of natural resource endowments, causes environmental degradation, costs governments in lost revenue (Koyunen & Yilmaz 2009) and promotes corruption (Mendes, 2011).

Data on illicit trade of goods and other illegally produced flows including natural resources is scarce (Haken, 2011). Chaudhary et al. (2017) while facing the problem of data availability. Finer et al. (2014) and Kleinschmit et al. (2016) state that even the FAOSTAT trade database does not have data on illegal wood being traded.

Illegal timber harvesting has connections with militancy and this conflict timber has accelerated the pace of illegal logging. Forests in Kashmir (disputed area between Pakistan and India) and areas in Khyber Pakhtunkhwa remain vulnerable to illegal harvest by militant groups (Forester et al., 2003). Illegal wood is smuggled between Afghanistan and Pakistan (Giordono, 2009; Peters, 2010; The News, 2010). The timber smuggled from Pakistan is re-exported back to Pakistan to declare it as duty-free Afghan timber (WCS. 2008). Once the wood i s smuggled to Pakistan it is destined to Karachi and onward to the Gulf States (Bader et al., 2013). However, there is no data showing the scale of such timber. Further, there is no data showing the classification of consumers with respect to the consumption of illegal wood. Overall wood supply and demand analysis in the country shows that the household sector is the largest consumer mainly for fuel-wood and the construction sector is the largest consumer (20%) of timber (Zaman and Ahmad, 2012). A study conducted by UNOCD & SDPI (2011) mentioned that in terms of quality, the timber trade data of Pakistan is poor. There is a need to conduct more studies on estimating forestry data to develop a strong data-base for analysis.

Considering the fact that forest area in Pakistan is already very low (5.1%) (Bukhari et al., 2012) and the data base is weak, the present study addresses the question of illegal wood harvest from State owned forests of Pakistan. The present study is a first attempt to use system dynamics methodology to estimate macro level data on wood consumption, wood supply and illegal logging in the country. The purpose of using systems methodology is to derive the system components from time series data. In our case, we are concerned with the estimation of the illegal wood trade in Pakistan. Once the systems components are developed and values are estimated, the time series data generated through system dynamics then helps to estimate illegal wood harvest in the country. The present model is developed in such a way that it has incorporated the sources of wood supply and total wood consumption in the country. One of the main difficulties in developing the model was that the time series data on wood supply was not available. For this purpose, the information has been retrieved from the literature. This information was available in reports (see methodology), and later converted into equations to incorporate in the model. Thus, the model results would add to the data-base of the forestry sector and would help to estimate wood extraction by different interest groups and illegal wood being consumed by different consumer groups in the country. The present study will help the policy makers and environmentalists to know the scale of the illegal logging economy in Pakistan. The model developed by the present study would be a sample model for other developing countries where there is not a complete set of data to estimate systems variables for the forestry sector (discussed in section 3).

State-owned forests in Pakistan are vulnerable to illegal logging as farmlands in the country are the property of individuals and families, and are therefore being protected by families themselves. State-owned forests' contribution to total wood consumption in the country may or may not be equal to the wood officially harvested from State-owned forests. Wood officially harvested from the State-owned forest as highlighted in official documents is far less than wood supply contribution from State-owned forest to total wood consumption in the country (see for example PFI, 2004; Clark, 1990; GOP, 2005). The gap between the two may be considered illegal wood harvest from the State-owned forest, considering the fact that wood imports have declined sharply as discussed below in the methodology section.

The primary objective of the present study is to review the estimated data and methods describing the scale of illegal logging in Pakistan. The focus of the study is to figure out the key dynamics of illegal wood harvest in Pakistan. The difference between the volume of wood from State-owned forest that contributes to wood consumption, and the official data showing wood extraction from State-owned forest, serves as an estimate of illegal harvesting. The sources of wood supply contributing to wood consumption in the country are analyzed for comparison with the officially harvested wood from State-owned forest. The value of illegal wood harvest is estimated and added to the total wood consumption in the country. The share of illegal wood to the Gross Domestic Product is also calculated. The study concludes with some policy suggestions.

The paper is structured as follows. Following the introduction and the objectives of the research, a review is given highlighting the literature on the volume of illegally logged wood. The methods used to estimate illegal logging are also discussed. The methodology based on system dynamics model is elaborated by developing a graphic model with its mathematical equations. The model results are validated in the light of official data and conclusions are drawn with some policy suggestions.

2. Review of Volume and Methods of Estimating Illegal Logging

At a global level, the value of the black-market economy is about $1.81 trillion (UNEP & INTERPOL, 2012) and the value of illegal logging is about $7 b (Haken, 2011). The value of the black market in Pakistan is about $6.53 b, and the value of illegal logging is $782 m (Roul, 2009). Some other estimates show this value as Rs. 835 million per annum. This was based on the average annual recorded illegal cutting of about 50,000 m^3 and an average timber price in 2005/06 of Rs. 16,700 (US$ 196.5 approximately) per m^3 (UNOCD & SDPI, 2011). A forest harvesting ban has been imposed since 1993. It is believed that the illegal logging continued even after the ban and the volume of illegally logged wood may be ten times more than the legal timber harvest (Hausler et al., 2000) as cited in (Fischer et al., 2010). This ban has had the effect of driving timber harvesting into illegal markets (Suleri, 2002). The Royal Institute of International Affairs mentioned that the estimated value of global trade in wood products is $150 billion and illegal global forest activity accounts for more than 10 times that figure (RIIA, 2003).

At the time of independence, Pakistan had 7% of its land area under forests. This declined to less than 5% after the separation of Bangladesh in 1971 (Fischer et al., 2010). The deforestation in the country is about 2% (Ma &Broadhead, 2002) and the net area under forest in the country is 4.55m hectares (Bukhari et al., 2012).

Globally, the estimates on illegal logging are based on different methodologies, including wood flow analysis (Contreras- Hermosilla et al., 2007; World Bank 2006; Contreras-Hermosilla, 2000); interview based information (WWF Latvia, 2003; World Bank, 2005; Rhodes, Allen & Callahan, 2006); comparing import and export statistics (Birikorang, 2001; Blaser et al., 2005; Lawson & MacFaul, 2010) and the difference between the prices paid to the loggers and the final market prices of wood (Solinge & Boekhout, 2008). These estimates are expressed in terms of percentage share to GDP (Solinge & Boekhout, 2008). Supply-demand gap has been used as a proxy for the analysis of illegal logging in many studies (Manurung et al., 2007; Tacconi, 2007; Harwell, 2009). The level of illegality varies with changes in demand and supply of wood and is affected by multiple factors like implementation of laws related to certification, level of sustainable harvesting, trade flows from one country matching with the recipient country, etc. (Wellesley, 2014; Hoare, 2014; Wakker, 2014; Lawson, 2014; Barr et al., 2010). Game Models are being used which are a helpful tool to identify the channels of illegal logging (Lee et al., 2015). Songchoo and Suriya (2012) also discussed game theory as helping to make policy decisions to control illegal logging. Lack of identification information is also a problem in the way of curbing the crime. A range of scientific forensic methods; visual identification methods, chemical methods, and genetic methods, have been developed to provide identification information as criminal evidence (Dormontt et al., 2015).

Haken (2011) cited the Seneca Creek and Wood Resources International report estimates, that show illegal forest activity as representing 5% to 10 % of global industrial production, and volume of illegal logged round wood that enters international trade represents one percent of global production for both softwood and hardwood. Haken (2011) further cited estimates of a 2007 report that the global forestry sector accounts for about one percent of world Gross Domestic Product. The CIA World Factbook estimated the 2009 world GDP at $70.17 trillion, which would set the 2009 value of global wood production at $701.7 billion. Based on the Seneca Creek and Wood Resources International estimate of one percent, the said report calculates the value of suspicious wood in the international market to be around $7 billion in 2009. This is consistent with the Seneca Creek and Wood Resources International estimate of $4.9 billion in 2004 when world GDP was $42 trillion. Contreras- Hermosilla et al. (2007) also mentioned that the forest products' sector is contributing about 1% of world GDP and stands at 3% of international merchandise trade.

3. System Dynamics Methodology

System dynamics helps in understanding the time varying behavior of complex systems (Musango et al., 2012). System dynamics models are developed by constructing stocks and flows of information, data as sets of differential equations linked through intermediary functions and data structures (Gilbertand Troitzsch, 1999). Human and ecological interactions can be represented within these models (Baker 1989; Sklar and Costanza, 1991). In the present study, the stocks and flows of wood and forest area in the country with population dynamics and wood consumption helped to derive information on wood supply and wood consumption by constructing functional relationships between legal and illegal wood harvest with respect to time.

3.1 A System Dynamics Model for Evaluating Illegal Wood Harvest

In order to explain the methodology a conceptual figure (1) is depicted to explain the key variables of the model. The figure shows the basic conceptual design of wood supply and wood harvesting on which the system dynamics model has been built. Our study is based on the hypothesis that the legal wood harvest from State-owned forest land and wood supply contribution from State-owned forest to total wood consumption are not equal; therefore, the gap between the two is counted towards illegal wood harvest.

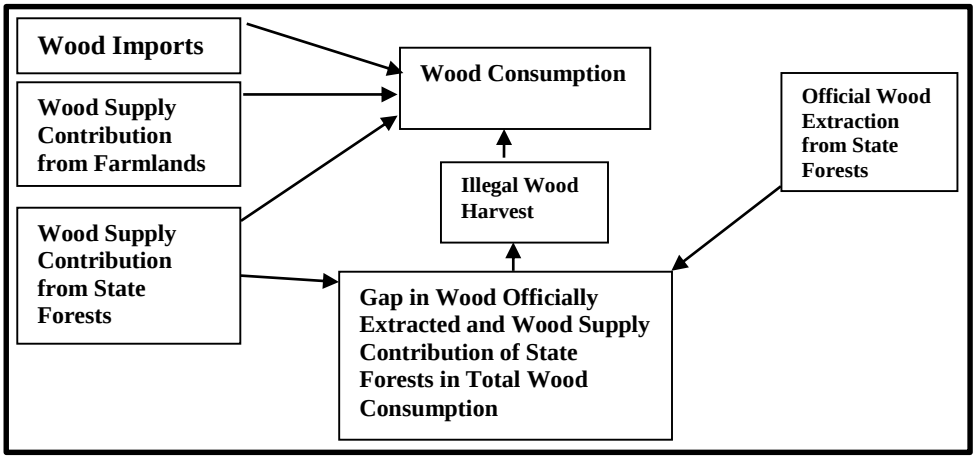

Figure 1: Structural Concept of the Sources of Wood Supply and Wood Consumption

In Pakistan, the official sources do not provide time series data on wood supply. A thorough process of information collection from the literature has been done for the present study. The information was available in statement forms. This information on the contribution of each source of wood supply in terms of its share to total wood consumption in the country is sorted out. The statements have been put together with respect to time (section B) and converted into model equations (see appendix). Other variables, including the consumption of wood in the country and wood harvest from State-owned forest have been incorporated in the model. Further, the model highlighted population growth as well. Since consumption of wood in the country is increasing with population growth, power shortages and the lack of alternative energy resources (electricity, gas, nuclear energy), are pushing up the wood consumption. In the case of Pakistan, in the pre-harvesting ban period, the supply share of wood from State-owned forests was higher than (legal) wood extraction from State- owned forests. After the ban, official information stated that the supply share from State-owned forest declined (see FAO., 2009; UNDP-ECC, undated; Clark, 1990; GOP., 2005), but according to some studies, the illegal wood supply had not declined after the ban (Fischer et al., 2010; Shahbaz & Suleri, 2009). There was a wood shortage of 29.361 million m^3 in the country that has grown at 2.1% annually from 1992 to 2003 (UNDP-PK-ECC, undated). Thus, the volume of pre-ban period wood supply from State-owned forests helped us to check the trends in wood supply after the ban from State owned forests, which in turn provides a base to determine the trend of wood illegally harvested from these forests. Studies show that after the harvesting ban, the illegal wood supply from State owned-forests has increased (see Fischer et al., 2010; Shahbaz and Suleri, 2009; Hausler et al., 2000), which is contrary to the official claim that after the ban the supply share of State

owned forests has declined. This leads us to design the present study to compare the data on wood supply share of State owned forests in wood consumption and wood officially harvested from State owned forests. Any gap between the two sets of the estimated values is considered as illegal wood harvest. How much is the "gap", is a task being solved below with the help of a model built in Stella to develop time series data on the wood supply share of State forests and wood legally harvested from State owned forests to determine the value of illegal wood harvest over time simulating up to the year 2029-30. Once the level of illegal wood harvest is estimated, it is added with legal wood harvest thus estimating the total wood consumption in the country over time. The methodology of estimating illegal wood harvest is based on the idea taken from the work of Manurung et al. (2007), Tacconi (2007), and Harwell (2009), in which they used the gap between demand and supply of wood as a proxy for illegal wood. However, the present study considers the gap between official wood extraction from State forests and wood actually supplied and consumed from the State- owned forests in Pakistan.

Based on the structure described above, a model was built in Stella 10.1(Figure 2) to generate time series data on wood supply. The share of each source of wood supply depends on how much each source is contributing to total wood consumption. The information has been collected in statement form (see below sector frame B with italic statements).

The model is divided into four sectoral frames: human population; sources of wood supply; national wood stock availability; and illegal wood extraction. Sources of wood supply are set on the basis of the share of each supply source in wood consumption. The model is based on time series data from 1990-2010 and projection estimates are highlighted for 2029-30.

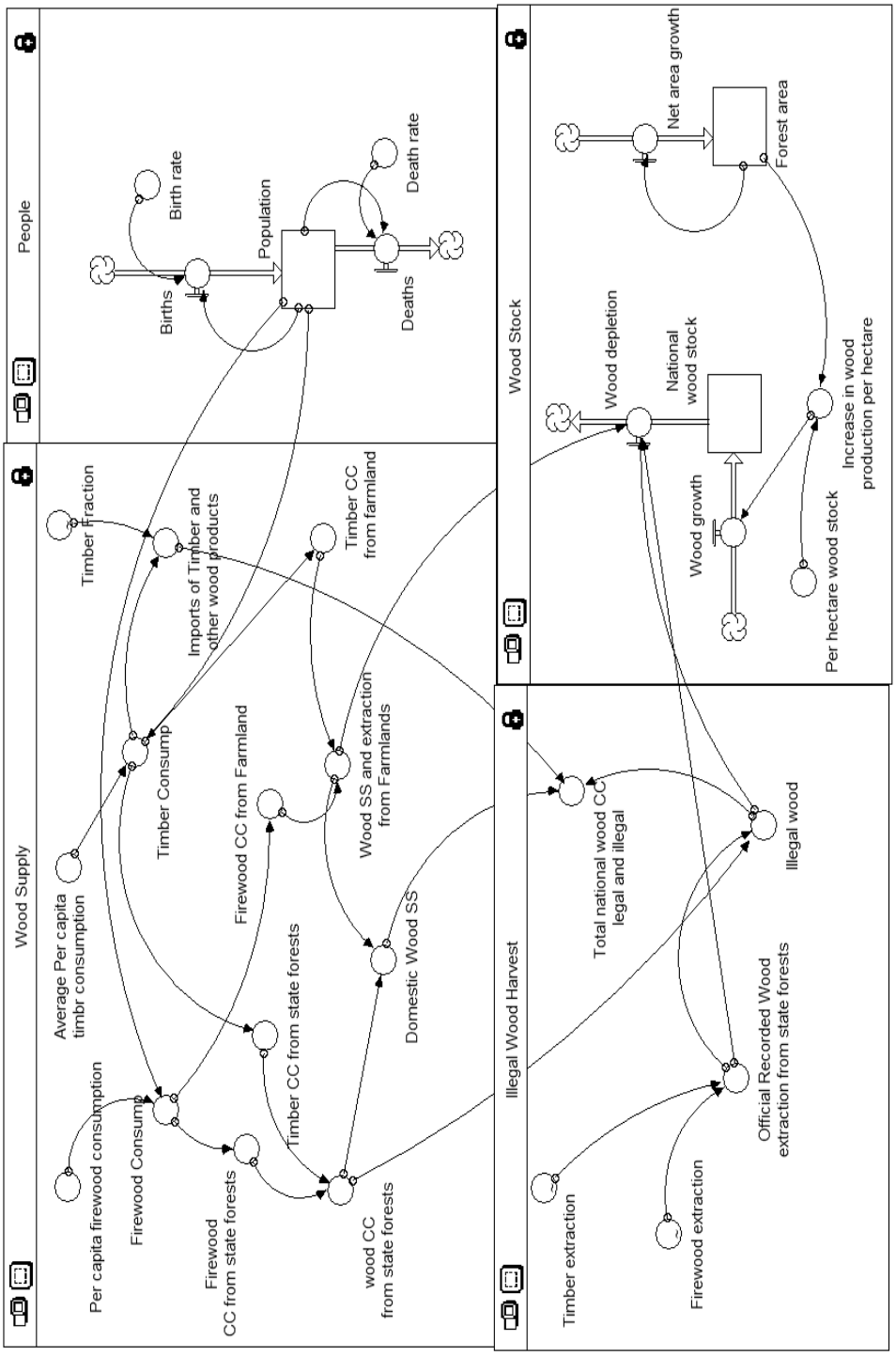

Figure 2: Model Showing Wood Supply, Wood Consumption and Wood Harvest

3.1.1 Sector Frame "People"

The population growth is presented in sector frame "People". The data on population is given in equations below. Based on the growing population, using per capita timber and firewood consumption, the growing trends in wood consumption are calculated over time.

3.1.2 Sector Frame "Wood Supply"

There are three sources of wood supply in the country: State owned forests, farmlands and imports. The values of per capita firewood consumption and per capita timber consumption in the country are taken from FBS (2010), GOP (2005) and Zaman & Ahmad (2012). The information to calculate percentage share of wood supply contribution to total wood consumption from all three sources and wood supply from State owned forests, farmlands and imports are taken from FAO (2009), UNDP-ECC (undated), Clark (1990) and GOP (2005), and are summarized below. This information is available in statement forms. With the help of the systems model, the information is then converted into equations (see model equations) to generate time series data given in table 2 (appendix).

Imports during the 1990's were 41% of the total timber consumption, later decreased to 20% in 2000's and then to 5% during 2005-2010. Out of total firewood consumption, from 1990 till 1996, 10% of the firewood consumption was supplied by State-owned forest. After 1996, the figure dropped to 0.91%. Out of the total timber consumption, from 1990 to 1995, timber consumption from State-owned forest was 18%, in 1996 it became 10% and from 1997 onward it dropped to 8%. From 1990 to 1995, timber supply from farmlands was 41%, for 1996 it became 63% and from 1997 onward it increased to 72% of the total timber consumption. Out of total firewood consumption, from 1990 till 1996, 90% of the fuel- wood was supplied by farmlands and the remaining 10% by the State-owned forest. After 1996, this ratio changed to 99.09% and 0.91% respectively".

3.1.3 Sector Frame "Illegal Wood Harvest"

Wood consumption from State owned forests has been explained above. Total wood, legally harvested from State owned forests are the summation of timber and firewood extraction from state owned forests. The data on official wood harvest/extraction (including timber and firewood) represents government statistics on wood harvest from State-owned forest, given in table (2) in appendix. Illegal wood harvest is calculated on the basis of the difference between total wood consumption from State owned forests and wood officially (legally) harvested from State owned forests. Principally, the wood supplied from the State-owned forest and official recorded wood harvest from State-owned forests should be equal. Any discrepancy in these figures should give an estimate of an illegal wood harvest.

3.1.4 Sector Frame "Wood Stock"

Wood stock in the country is taken as wood stock from State-owned forest and from farmlands. In 1992, the Forestry Sector Master Plan estimated a total national standing volume of wood as 368 million m^3; farmland standing stock as 70.3mm^3 and farmland stock growth per annum as 7.7 million m^3 per year. These estimates are based on the data from Forest Department working plans, the farmland tree survey and the Household Energy Strategy Study (HESS). The total wood yield per annum was estimated as 10.9 percent of the standing stock (EC-FAO, 2002). Based on 10.9% value, the national wood yield growth

per year is calculated as 40.112 million cubic meters. Change in wood stock also comes from change in forest area. Therefore, the net change in total forest area (forest area growth) in the country is also incorporated in the model to add per hectare yield growth in the wood stock. The forest area was 3.46 million hectares in 1990 that increased to 4.26 m hectares in 2010-11, showing an increase of 1.2% per annum. This increase is mainly attributed to farmland growth as mentioned by FAO (2007). Wood extraction is the result of wood harvest from State owned forests, from farmlands and wood illegally extracted, thus affecting wood stock availability. Wood stock, forest area and other auxiliary variables shown in Fig. 2 are expressed in model equations. The estimated model data is given in table 1 & 2.

3.2 Estimating Illegal Wood Harvest to Gross Domestic Product (GDP) Of Pakistan

In our model, GDP based calculations are not part of the Stella built model but have been used to determine the monetary value of illegal wood estimates. The model value of illegally harvested wood has been used to estimate its monetary value and to find out its percentage contribution to GDP.

To estimate the monetary value of illegal wood harvest, wood prices given by UNODC & SDPI (2011) are used, where the average price of wood is Rs. 16700 per m^3 in 2005-06. Keeping in mind the non-availability of time series data for the prices of wood, this value (average price per m^3) is then used to determine the monetary value of illegal logged wood for the period under study. The estimated monetary value of illegal wood is used to determine its contribution to GDP of the country. World GDP to illegal logging relationship estimates by Haken (2011) and Seneca Creek Associates, LLC, and Wood Resources International (November 2004; November 2009) show that in 2009, global GDP was $ 70.17 trillion, global wood production was 1% of the GDP ($ 701 b), and global suspicious wood production was 1% of global wood production ($ 7 b). FAO (2012) and Agrawal et al. (2013) also mentioned the same criteria that forestry is contributing nearly 1 percent of the global GDP. Based on this information, the estimates of the present study are then compared with the global standards.

4. Results and Analysis

4.1 Model Validation Based on Past Data from 1990-2009

Model results are checked in the light of data taken from official sources. Three key variables are selected for comparing model data and official data. The three key variables are population, which is the driving force of wood consumption; forest area as the main source of wood stock in the country; and wood consumption. These data are graphically presented with results from the present model to compare the two. There is no significant difference between the trends of growth found in official data and model data on population, forest area and also on wood consumption, thus validating the results of the model (Table 1, Fig.3 a &b). Therefore, the projection based on this model is reliable.

Table 1: Estimated Model Data and Official Data for Model Validation

Years	*Official data- Population (m)	Model Data- Population (m)	Years	**Official data- Wood Consumption (mm3)	Model data- Wood Consumption (mm3)	Years	***Official data- Forest Area (m. ha)	Model data- Forest Area (m. ha.)
1990	112.27	112.27	1990	25.38	25.726	1990-91	3.46	3.46
1991	112.61	114.3	1991	27.523	26.191	1991-92	3.47	3.5
1992	115.54	116.36	1992	27.08	26.663	1992-93	3.48	3.54
1993	118.5	118.46	1993	29.815	27.145	1993-94	3.45	3.59
1994	121.48	120.6	1994	30.53	27.635	1994-95	3.6	3.63
1995	124.49	122.77	1995	31.243	28.134	1995-96	3.61	3.67
1996	127.51	124.99	1996	31.955	29.454	1996-97	3.58	3.72
1997	130.56	127.25	1997	32.576	30.399	1997-98	3.6	3.76
1998	132.25	129.54	1998	33.425	30.948	1998-99	3.6	3.81
1999	136.69	131.88	1999	34.298	31.506	1999-00	3.78	3.85
2000	139.96	134.26	2000	35.192	32.075	2000-01	3.77	3.9
2001	142.86	136.69	2001	35.57	32.654	2001-02	3.8	3.95
2002	146.02	139.15	2002	59.716	33.243	2002-03	4.04	3.99
2003	149.32	141.66	2003	30.141	33.843	2003-04	4.01	4.04
2004	152.66	144.22	2004	30.994	34.454	2004-05	4.02	4.09
2005	156.04	146.83	2005	31.649	35.076	2005-06	4.03	4.14
2006	159.46	149.48	2006	31.762	35.71	2006-07	4.21	4.19
2007	162.91	152.17	2007	34.98	36.354	2007-08	4.21	4.24
2008	166.41	154.92	2008	35.274	37.01	2008-09	4.24	4.29
2009	169.94	157.72	2009	36.615	37.678	2009-10	4.23	4.34

Source: *Supply and demand of fuel wood and timber for household and industrial sectors and consumption pattern of wood and wood products in Pakistan, Government of Pakistan 2005, Ministry of Environment, Government of Pakistan. ** Compendium on Environment Statistics of Pakistan 2010, Federal Bureau of Statistics, Islamabad- values are rounded off. ***Land Cover Atlas of Pakistan, 2012

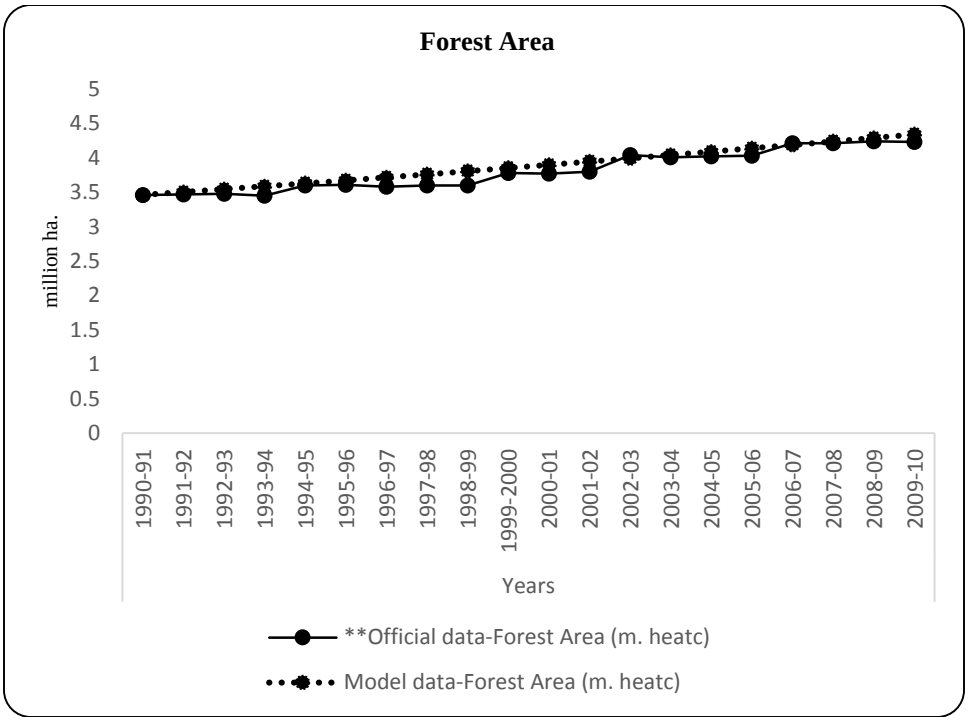

Figure 3: Comparing Model Data and Official Data on Forest Area (M. Hec.)

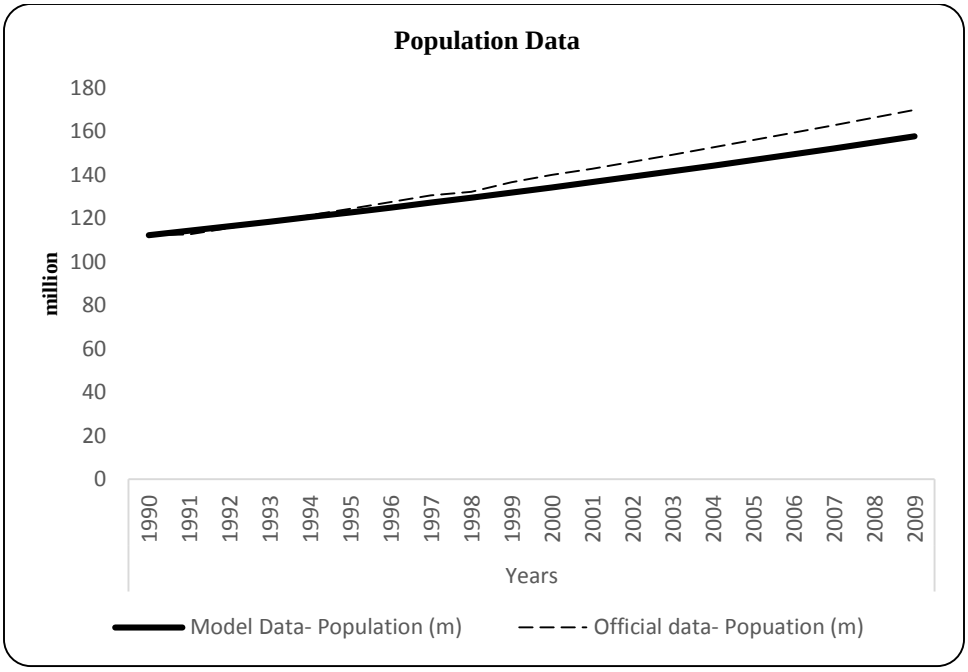

Figure 4: Comparing Model Data and Official Data on Population (M)

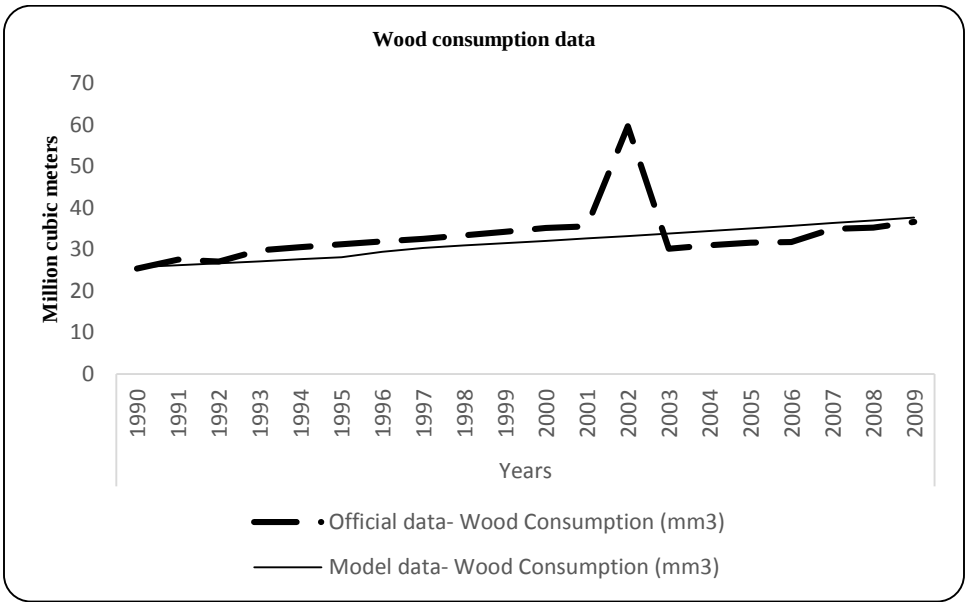

Figure 5: Comparing Model Data and Official Data on Wood Consumption (Wood Imports and Illegal Wood Excluded)

The official available data on wood consumption covers the consumption of timber and firewood from state owned forests and from farmlands. The data on imported wood is not included in the official data on wood consumption. Therefore, for validation, we also selected the same two classes of model generated data for wood consumption; consumption of timber and firewood from state owned forests and from farmlands (Table 1). The results show that the official data and estimated model data on wood consumption from these two sources are not significantly different from each other (Figure 5). Thus, based on the uniformity between the model data and official data on wood consumption in two wood consumption categories, we can proceed with the rest of the estimation i.e. estimating illegal wood and estimating time series data on imported wood to calculate "Total wood consumption". If model-estimated data on illegal wood harvest shows a rising trend over time, then we will accept the claim that illegal logging increased even after the harvesting ban. If the trend is declining, it would mean that the official claim of decreasing supply share of State owned forests and increasing contribution of farmlands, is more reliable.

4.2 Projection based on Past Trends

Since the model data has been validated on the basis of official data, the model results allow us to make a projection for the period 2029-30. The projection is made for the key variables: forest area of Pakistan; national wood stock availability; official wood extraction; and illegal wood harvest from state forests.

4.2.1 Forest area and National Wood Stock

The forest area in the country was 3.46 million hectares in 1990, having a wood stock of 368 million m^3 with the estimated growing stock of 40.112 million m^3 per annum. The results show that wood stock has increased to 1441.3 million m^3 in 2010. Simulating on

the basis of estimated growth, the wood stock availability in the country would be 4255.3 million m³ in 2029-30. This growth in wood stock is net growth i.e. after deducting legal and illegal wood extraction from State-owned forests and wood harvest from farmlands. The model results show that the forest area would be 5.5 million hectares in 2029-30.

4.2.2 Official Recorded Wood Extraction and Illegal Wood Harvest from State-Owned Forests

On the basis of official firewood harvest and timber harvest from 1990-2010, the total official recorded wood harvest (legal) in terms of volume has increased from 0.616 million m³ in 1990 to 0.719 m³ in 2010 with projected estimate of 0.543 million m³ for 2029-30. Here one thing is important to note that in terms of volume, the officially harvested wood from State-owned forests has increased in later years as compared to 1990 levels, but in terms of share contribution to wood consumption, after the timber harvesting ban in 1993, the State-owned forests supply share has declined as mentioned by official data. There is a gap between wood supply share of State-owned forests as shown by official data and wood legally harvested from State-owned forests. The value of illegal wood harvest from State-owned forests is estimated approximately 2.6 million m³ in 1990 that has decreased to 0.172 million m³ in 2010 and is projected at 0.708 million m³ in 2029-30. Model data shows that the total wood consumption of farmland wood, imported wood, legal and illegal wood consumption from State-owned forest stands at 30.4 million m³ in 1990 and is projected to increase to 55 million m³ by 2029-30.

4.2.3 Estimates of Illegal Wood and Ratio to GDP in Pakistan

From 1990 to 2010, the average contribution of forestry in Pakistan was 0.33% to the GDP. The model value shows that in 2005, the volume of illegal wood harvest was 0.475 million m³. The GDP value Rs. 7158527m at constant factor costs for the year 2005 is used to calculate percentage share of illegally harvested wood. The year 2005 is selected for comparison only because the prices of wood and comparative estimates were available for that year. On the basis of prices of wood in 2005-06 (Rs. 16700 per cubic meter) the value stands as Rs.7932 m. This estimated monetary value of illegally logged wood shows that illegal wood is 0.11% of the GDP of the country. If we add the value of illegal wood share to GDP to the value of 0.33%; an average share of forestry to GDP, the actual share of forestry becomes 0.44 % to the GDP. On the basis of the data from 1990 to 2010, a net area growth of 1.2 % has been observed. The growth in forest area resulted in additional growth in wood stock which was already growing at 40.112 million m³ per annum. However, the wood stock is being depleted by wood cutting in the country. The wood is being cut from State owned forests and from farmlands. The wood stock is also affected by illegal wood cutting. We added the estimated data on illegal wood harvest to the wood being depleted over time. Thus, total wood depletion increased at 2.3% per year, however stands lower than the growth of wood stock (11.7%) thus making wood stock available for wood consumption in the country. The illegal wood harvest is found at points where there is a gap between wood legally harvested from State owned forests and supply share of these forests to total wood consumption. After the harvesting ban in 1993, the supply share of State owned forests has decreased. The estimated value of illegal wood cutting shows that after the ban, its consumption from State owned forests has declined. The decline in the supply share of State owned forests to total wood consumption has been decreasing and has been compensated by increase in the supply share of farmlands. Since the farmlands are private lands and are not under threat of illegal wood cutting, we thus conclude that illegal wood cutting decreased after the ban and the wood supply share of farmlands has

increased. Farmlands are now providing 72% of timber and 99.09% of the firewood in the country. Using global standards to compare illegal wood contribution, our estimates for illegal wood harvest stands at 1.5% of the total wood production of the country in 2010, which is higher than the global suspicious wood share to the global wood production i.e. 1%. Further, average share of forestry to GDP (including estimated illegal wood) in Pakistan is 0.44% that is less than the global average of 1%.

On the whole, it is found that the official data on wood harvest does not match the supply share of wood from each source. For example, going back to the literature reported level of illegal wood extraction which is said to be 10 times more than the legal wood harvest from state owned forests, the official value for illegal wood may be equal to 6.16 m. cubic meters for the year 1990 (calculated on the basis of officially harvested wood value for the year 1990). By adding this value to the rest of wood supplied by other official sources-- Imports, farmlands wood supply and wood supplied by state owned forests--the total officially declared wood supply may be equal to 33.6 mm3, which is more than 25 mm3; the official estimate of wood consumption (FBS, 2010) for the year 1990, thus invalidating the claim that the illegal wood is 10 times more than legal wood harvest.

On the other hand, model data calculates the total wood supplied by three sources; imports, state owned forests, farmlands and illegal wood to arrive at a total level of wood consumption in the country of 30.4 mm3 for the year 1990. On the basis of the model values, the value for illegal wood stands at 4 times the legal wood harvest from State owned forests for the said year. The trend in illegal wood harvest is declining after 1990, mainly because the share of farmlands' wood in the total wood consumption has increased overtime.

5. Findings and Conclusion

Illegal logging is a threat to forest resource management. Pakistan, already having low forest area, is facing the challenge of illegal wood cutting from State-owned forests. How much illegal wood is being extracted from these forests, was a question that has been addressed in the present study. An effort has been made to estimate illegal wood harvest at the macro level in Pakistan. The official data on wood consumption is the sum of timber and firewood consumption in the country. This data has been checked and compared with the available information on supply of wood from three sources: wood imports, wood supply from State forests, and wood from farmland. The estimates on wood officially extracted from State forests have been checked and compared with the wood supply from state forests. These two estimates are found to be significantly different from each other, thus providing a base for estimating illegal wood extraction from State owned forests. A review of the literature showed that there is no time series data on wood imports. Time series data on wood supply from each source-- imported wood, supply of wood from state forests and from farmlands-- was not complete, thus leaving a big challenge for the present research to build time series data by converting statements into mathematical equations, and incorporating it into a system dynamics model that has an inbuilt capability to generate time series output. The present study thus has used these estimates of wood supply to determine the total wood consumption by including all categories of wood: wood from imports, from State owned forests, from farmlands and illegal wood consumption. The basic argument was that since farmlands are under private ownership, State- owned forests are vulnerable to illegal wood harvest in the country. The study by Badshah et al. (2014) also showed that a significant difference has been found between the average annual

removal of wood and wood consumption in hilly areas of Pakistan. Using a system dynamics model, we found that there is a gap between estimates on wood officially harvested and consumed in the country, which represents illegally harvested wood. The results further show that the illegal wood harvest was 4 times the official wood harvest during the pre-harvesting ban year i.e. 1990. The contribution of illegal wood to GDP for the year 2005-06 is estimated at 0.11%, making the average share of forestry to GDP 0.44% i.e. lower than the global average of 1%. The model results have been validated based on the official data on forest area, population growth and wood consumption.

Based on the above estimation and analysis, it is imperative to devise policies to control illegal logging. Wood consumption in third world countries, especially where law enforcement is weak, results in illegal cutting and bribery. It is suggested by Songchoo and Suriya (2012) that this situation can be controlled by giving high rewards for arresting criminals. Game Models are also a useful tool to identify the channels of illegal logging. Lee et al. (2015) used this technique and found that the education of law enforcement officers and information on corrupt officials have significant effects in controlling corruption. In the presence of week institutions, natural resources should be managed by communal management groups as suggested by Pellegrini (2007).

Access to natural resources is another impediment resulting in ruthless use of the resource and making its control difficult. The theory of access helps to identify how much the stakeholders have access to natural resources (see for example Ribot and Peluso, 2003). This notion can be used to find the reasons for the gap between the consumption and production of wood. Forensic methods have also been devised to identify the illegal wood and the source from which it has been brought. These measures not only help to address the menace of illegal logging but also help to identify the factors and variables that can be used to estimate the volume of wood illegally extracted.

6. Contribution of the Study

The model developed under the present study is the first of its kind that has generated results on key variables for which the time series data was not available. The model includes wood stock, wood imports, and total supply of wood from farmlands and from national forests (Table 2, appendix). The results generated by the model would add to the data-base of the forestry sector of the country. Data on the key supporting variables--forest area, population growth and the past trends of wood consumption-- validate the model results. We also used projection by the model to estimate the demand supply gap of wood in the country. The results are helpful in analyzing energy policies, sustainable natural resource management and controlling illegal wood harvesting in the country. Since population growth is driving the wood consumption mainly because of a need for fuel wood, it is imperative to work on fuel wood substitutes. There is a need to work on estimating other key variables that contribute to illegal timber harvesting, like timber harvested by militants and other illegal timber consumption.

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Appendix

Data and Model Equations

Forest area and wood growth

INITIAL Forest area = 3460000 ha.
Forest area (t) = Forest area (t - dt) + (Net area growth) * dt
National wood stock (t) = National wood stock (t - dt) + (Wood growth – Wood depletion) * dt
INITIAL National wood stock = 368000000 million m^3
Per hectare wood stock = 106.4 m^3

Wood stock growth (m^3) = 40112000+ Increase in wood production per hectare
Wood stock depletion (m^3) = Illegal wood extraction from State-owned forest + Official Recorded Wood extraction from State-owned forest + Wood Supply and extraction from Farmlands

Population Growth

Population (t) = Population (t - dt) + (Births - Deaths) * dt
INITIAL Population = 112270000
Births = Population*(Birth rate/1000)
Deaths = Population*(Death rate/1000)
Birth rate = 25.45
Death rate = 7.4

Wood Consumption and wood supply

Average Per capita firewood consumption = 0.201754698 m^3
Average Per capita timber consumption = 0.046429402 m^3
Domestic Wood Supply = wood consumption from State-owned forest + Wood Supply and extraction from Farmlands
Total national wood consumption legal and illegal = Domestic Wood SS +Imports of timber + illegal wood
Official Recorded Wood extraction from State-owned forest = Timber extraction + Firewood extraction
Wood Consumption from State-owned forest = Timber Consumption from State-owned forest + Firewood Consumption from State-owned forest
Wood Supply and extraction from Farmlands = Firewood from Farmland + Timber from farmland

Wood Supply and wood Consumption variation with respect to time

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 Consumption from State-owned forest = 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
Firewood from Farmland = IF TIME<=1996 THEN 0.90*Firewood Consumption ELSE 0.9909 *Firewood Consumption
Firewood Consumption from State-owned forest = if time <= 1996 then 0.1 *Firewood Consumption else .0091 * Firewood Consumption

Table: 2 Official Data and Estimated Model Data

Year	Population (m)	National wood stock (m m3)	Forest area (m. ha.)	Official Recorded Wood extraction from state forests (m m3)	Imports of Timber and other wood products (m m3)	wood Supply share from state forests (m m3)	Wood Supply from Farmlands (m m3)	Illegal wood (m m3)	Total national wood Consumption including illegal wood (m m3) (sum of column 6 to 9)
1990	112.27	368	3.46	0.616	2.137	3.203	22.523	2.587	30.451
1991	114.3	382.39	3.5	0.612	2.176	3.261	22.93	2.649	31.016
1992	116.36	400.72	3.54	0.564	2.215	3.32	23.343	2.756	31.635
1993	118.46	423.06	3.59	0.569	2.255	3.38	23.765	2.811	32.211
1994	120.6	449.44	3.63	0.813	2.296	3.441	24.194	2.628	32.559
1995	122.77	479.91	3.67	0.792	2.337	3.503	24.631	2.711	33.182
1996	124.99	514.51	3.72	0.62	1.567	3.102	26.352	2.482	33.503
1997	127.25	552.49	3.76	0.569	1.182	0.706	29.693	0.138	31.718
1998	129.54	594.26	3.81	0.55	1.203	0.719	30.229	0.169	32.32
1999	131.88	640.29	3.85	0.579	1.225	0.732	30.774	0.153	32.884
2000	134.26	690.61	3.9	0.562	1.247	0.745	31.33	0.184	33.505
2001	136.69	745.29	3.95	0.458	1.269	0.759	31.895	0.301	34.224
2002	139.15	804.37	3.99	0.25	1.292	0.772	32.471	0.522	35.058
2003	141.66	867.89	4.04	0.328	1.315	0.786	33.057	0.459	35.618
2004	144.22	935.91	4.09	0.305	1.339	0.8	33.654	0.496	36.289
2005	146.83	1008.48	4.14	0.34	0.341	0.815	34.261	0.475	35.892
2006	149.48	1085.65	4.19	0.365	0.347	0.83	34.88	0.465	36.521
2007	152.17	1167.47	4.24	0.228	0.353	0.845	35.509	0.617	37.324
2008	154.92	1253.99	4.29	0.232	0.36	0.86	36.15	0.628	37.997
2009	157.72	1345.26	4.34	0.294	0.366	0.875	36.803	0.581	38.626
2010	160.56	1441.35	4.39	0.719	0.373	0.891	37.467	0.172	38.903
2011	163.46	1542.29	4.44	0.731	0.379	0.907	38.143	0.176	39.606
2012	166.41	1648.15	4.5	0.757	0.386	0.924	38.832	0.166	40.308
2013	169.42	1758.98	4.55	0.794	0.393	0.94	39.533	0.146	41.012
2014	172.47	1874.84	4.61	0.779	0.4	0.957	40.246	0.179	41.783
2015	175.59	1995.78	4.66	0.728	0.408	0.975	40.973	0.247	42.602
2016	178.76	2121.85	4.72	0.686	0.415	0.992	41.712	0.306	43.425
2017	181.98	2253.13	4.77	0.65	0.422	1.01	42.465	0.36	44.258
2018	185.27	2389.65	4.83	0.628	0.43	1.028	43.232	0.4	45.09
2019	188.61	2531.49	4.89	0.613	0.438	1.047	44.012	0.434	45.931
2020	192.02	2678.7	4.95	0.639	0.446	1.066	44.806	0.427	46.745
2021	195.48	2831.33	5.01	0.679	0.454	1.085	45.615	0.406	47.56
2022	199.01	2989.46	5.07	0.655	0.462	1.105	46.439	0.45	48.455
2023	202.6	3153.14	5.13	0.615	0.47	1.125	47.277	0.51	49.381
2024	206.26	3322.43	5.19	0.619	0.479	1.145	48.13	0.525	50.279
2025	209.98	3497.4	5.25	0.632	0.487	1.165	48.999	0.534	51.186
2026	213.77	3678.11	5.32	0.636	0.496	1.187	49.883	0.55	52.116
2027	217.63	3864.61	5.38	0.64	0.505	1.208	50.784	0.568	53.065
2028	221.56	4056.99	5.44	0.593	0.514	1.23	51.7	0.637	54.081
2029	225.56	4255.29	5.51	0.543	0.524	1.252	52.634	0.709	55.118

Source: Estimated model data to build System Dynamics Model is based on the information taken from FAO (2009), UNDP-ECC undated), Clark (1990), EC-FAO (2002) and GOP (2005).