Analyzing the Sustainable Development Indicators of Nepal using System Dynamics Approach*

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Abstract

This paper delivers a cohesive system dynamic model for the assessment of sustainable development indicators, which will assist to explore the alternative scenarios of access to market, human well-being, environmental degradation, pattern of energy consumption, environmental balance, sustainability, and quality of life. This model is developed through the interaction of three pillars of sustainable development: social, economic, and environment. This theoretical framework will help policy makers and decision makers for sustainable development planning of not only Nepal but also other countries. The results exhibit the possible scenario of sustainable development progress in the study period. In addition, this model will create wider space for policy makers, professionals, academics, and researchers to analyze the interconnectedness of sustainable development indicators and their future prospects in the rest of the world.

Keywords: Sustainable Development, System Dynamic Model, Pillars of Sustainable Development, Indicators of Sustainable Development, Nepal

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Introduction

The concept of sustainability has been widely used in different sectors such as environment analysis, economic development and growth, fiscal management analysis, financial management, education, engineering, and medicine. More precisely, the concept of sustainability here refers more on protecting natural environment and enhancing the quality of life without affecting the capabilities of future generations. The development itself is very vague, which covers the social, economic, and environmental aspects of the economy. The dynamics of population, economy, and technology accelerate the environmental and social rates of change, which jeopardize the sustainability capability of people. The growing structural changes in the day-to-day life of human beings are being problematic to accelerate the sustainable development practices. Human system depends on a complex natural environment, which is fixed with the complex and adaptive community settings. Therefore, sustainable development, here, refers more accurately to the goal of sustainability of humankind.

This paper analyses a theoretical framework for an integrated system dynamic modeling of sustainable development indicators in Nepal. Further, the study appraises the national scale sustainable development indicators with the system dynamic modeling application to assess the quality of life and sustainability in Nepal on the span of 40 years (1995 – 2035). It is based on the theories and techniques of system analysis and systems-thinking approach. The main goal of this framework is to provide a technical decision support tool for stakeholders and decision-makers to analyze the quality of life indicators and future prospects of sustainable development in Nepal. It will expand the research scope on system dynamic modeling of sustainable development, defining indicators, and their inter-relationship among the indicators.

Background of study area

Nepal started periodic planning to facilitate and boost its developmental activities from 1956, and, since then, the periodic planning is still going on. Since the beginning of the development planning, Nepal endorsed a number of environment related legislations, specially focusing on protection of forest, wildlife, ecosystem, and biodiversity. The government started the basic needs approach to address the widespread poverty in the country from the Sixth Plan (1981-85). The Sixth Plan realized the environment as an inseparable aspect of the development process (Burlakoti, 2006) and introduced the national environment preservation policy and land use policy. After the Sixth Plan, the government of Nepal is always emphasizing the nexus of human needs, economic activities, and environmental factors. Nepal is already a signatory to a number of international treaties related to environment protection, and sustainable development. The Government of Nepal is taking major consideration on those international conventions, treaties, and agendas so that the socio-economic capabilities of people will be enhanced and sustainability will be maintained.

Although Nepal does not have an official National Strategies for Sustainable Development, Nepal has adopted the Sustainable Development Agenda for Nepal (SDAN), 2003, which is a major policy tool for all other development plans, policies, and strategies. The periodic plans, the Sustainable Development Agenda for Nepal (2003), and the Sustainable Community Development Programme (Nepal Capacity 21) govern the development framework of Nepal. These plans and policies are in line with national sustainable development strategy principles (DSD/DESA, 2009). This agenda has envisioned the over-arching goal of Sustainable Development in Nepal for 15 years (2016/17) to "expedite a process that reduces poverty and provides to its citizens and successive generations not just the basic means of livelihood, but also the broadest of opportunities in the social, economic, political, cultural and ecological aspects of their lives." This agenda has been translated as policy instruments for the Three Year Interim Plan (2007/08 – 2009/10), Three Year Plan (2010/11-2012/13), and Three Year Plan (2013/14- 2015/16). It provides the basic framework and guidelines to select and classify the sustainable development indicators of Nepal.

Conceptual Framework of Sustainable Development

The concept of sustainable development does not have a long historical background, but the concept of sustainability has long historical connections either religious or socio-cultural belief on protecting natural settings and adapting natural way of life. Ene et al. (2011) defined sustainable development as a fusion between economics and ecology that is not considered as doctrine or a theory. They further stated sustainable development as "a new term for an old idea: there is no viable economy without natural resources and no resources management without economic rationale" (Ene et al., 2011: 261). After the rapid industrialization in the western countries, these countries started to observe the change in climatic variation and realized the change in natural environmental settings.

The publication of “The Limits to Growth” in 1972 by Donella H. Meadows and her team, the Club of Rome, was a great milestone to analyze the future predictability of environment and earth system. Using system dynamics theory and a computer model called “World3,” the book presented and analyzed 12 scenarios that showed different possible patterns and environmental outcomes of world development over two centuries, from 1990 to 2100 (Meadows et al. 2003). Scientifically, it introduced Jay Forrestor's newly established computational approach of system dynamics modeling and quantitative scenario analysis into the environmental and sustainability analysis.

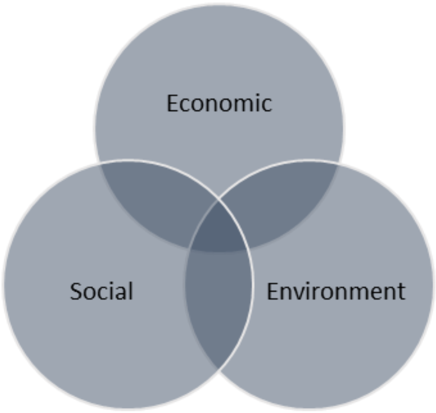
The theoretical framework for sustainable development developed through the series of international conferences on environment, nature conservation, bio-diversity, etc., to discuss and frame sustainability at the global and national scale between 1972[3] and 1992[4]. In 1983, the UN organized the World Commission on Environment and Development (WCED) and formed the commission chaired by Norwegian Prime Minister Gro Harlem Brundtland. The commission comprised of representatives from both developed and developing countries, to address the growing concern over the “accelerating deterioration of the human environment and natural resources and the consequences of that deterioration for economic and social development” (WCED, 1987). The commission formally defined the term “sustainable development” through the landmark publication of “Our Common Future.” The report popularized the definition of sustainable development: “Development that meets the needs of current generations without compromising the ability of future generations to meet their own needs” (WCED, 1987: 45). Brundtland’s concept of sustainable development became popular and widely used in academic, experimental, organizational, global, national, and local level, although it is very much vague and not easily measurable. On this ground, UNECE/OECD/Eurostat’s joint report states that ‘Sustainable development is a popular and important concept, but one that is difficult to define with precision and, therefore, difficult to measure” (UNECE/OECD/Eurostat WGSSD, 2008: 13). Bartonand Du Plessis (2000) explained the interconnectedness of three sectors: economic, social and environment as three pillars (see Figure 1) of sustainable development that could maintain the reasonable level of

[3] The UN Conference on Human Environment, Stockholm 1972, was the first global meeting discussing sustainability.

[4] The UN Environment and Development Conference, 1992, also called the Rio Summit or the Earth Summit.

balance to achieve sustainable development.

Figure 1. Interconnection among three pillars of Sustainable development



Source: Barton& Du Plessis, 2000

Broadly, the interactions among these three pillars give the way forward for sustainable development. Therefore, while adopting the policies on a particular sector, it is necessary to examine its ripple effects on other sectors. The balanced development of these three pillars will foster the path of sustainable development.

The way and progress of sustainable development can be observed thorough the indicator sets available in global, national, regional, or local level either in quantitative or qualitative formats. Nevertheless, it is very difficult to measure the ultimate goal of sustainable development through absolute measurable terms. Therefore, a country or community has its set of indicators based on a predefined framework that will forecast the level of progress towards sustainable development, which is in itself based on available national, regional, or local policies. Progress can be measured with a compilation of indicators that will give the possibility of formulating strategies to bring out priority areas of anxiety that will create attention on the pathway to achieving sustainable development goals in the future (Sorman, 2007: II).

Some Initiatives on Sustainable Development modeling

The Millennium Institute developed "The Threshold21 (T21) Sustainable Development Model" after more than a decade long effort in collecting and reviewing indicators of the different sectors, such as energy, environment, agriculture, demography, health, education, economy, industry, natural resources, politics, rural and urban development, and transportation. The interacting system dynamic model can be developed by integrating these indicators.

T21 is a Systems Dynamics model developed in Vensim and built with strict observance to causality that fully identifies the dynamic nature of the national development problem. It includes approximately 800 variables from demographics, agricultural production, health care, food and nutrition, international trade, national accounts, social services, energy and energy efficiency, goods production, education, and environment that assume the dynamic interconnection of the variables. T21 brings together economic, resource, population, social, and environmental issues in an integrated framework. It answers the question: How will the growth, social development, and environment of a country be influenced over the next twenty years, if policies shift investments toward one sector or another of the economy (Millennium Institute Professional Paper No. 17, 1998)? T21 can address the issues of poverty, economic and demographic growth, access to social services, environmental sustainability, energy transition, etc. It can be used for the overall socio-economic-environmental development, feedbacks, and delays of dynamic complexity, even though it misses short-term dynamics and does not consider local diversity (Bassi and Pedercini, 2007). Concisely, it has given further space to think about national development plan and national account system beyond GDP.

Bakkes (2012) analyzed BallagioSTAMP as policy-oriented sustainable development assessments in a large variety of application area, policy phase, and methodological approach. The benefit of BellagioSTAMP is to bring these insights easily available for any group assessing societal progress, considering policy options or advocating change (Bakkes, 2012). It shows that the BallagioSTAMP principles provide a wide angle for assessment of sustainable development indicators in local, national, and global scale.

Shi and Gill (2005) had explored the overall sustainability of ecological agricultural development in local level through the case study of Jinshan County in China. They developed a system dynamics model, the 'Agricultural-Institutional-Social-Ecological-Economic Model' (AISEEM), to assess long-term relations and dynamics of politics, economics, and environment involved in the ecological agricultural development (Shi and Gill, 2005).

The Agenda 21 adopted by the Earth summit, Threshold21 developed by

Millennium Institute, and The BellagioSTAMP Principles are the leading framework on sustainable development analysis. Further, the sustainability issues have been analyzed through the system dynamic approach since the publication of *The Limits to Growth*, in 1972. In recent days, system dynamics have become one of the major tools for the analysis of the interactions among the sustainable development variables and the forecast of the future of sustainability of the earth system. Further, the concept of the three pillars of sustainable development and their interconnectedness guide this paper to develop the theoretical framework for dynamic modeling of sustainable development indicators.

Developing Methodology, Systems, and Model

The earth system (socio-economic and ecological settings of the earth) is very much dynamic and interconnected. The change in one factor or indicator will bring about a number of internal and external effects on the system, and that leads to policy measures to respond to those disturbing factors. The indicators for sustainable development are guided by the system components that help to structure the search for indicators. Shi (2004) stated that a methodological synthesis of ecological economics and System Dynamics[5] modeling will provide an appropriate analytical framework and tool for developing the conceptual system dynamic modeling of sustainable development (Shi, 2004). Therefore, the methodology of this dynamic modeling rests on the theories and techniques of systems thinking and system analysis to explore the dynamics of the sustainable development.

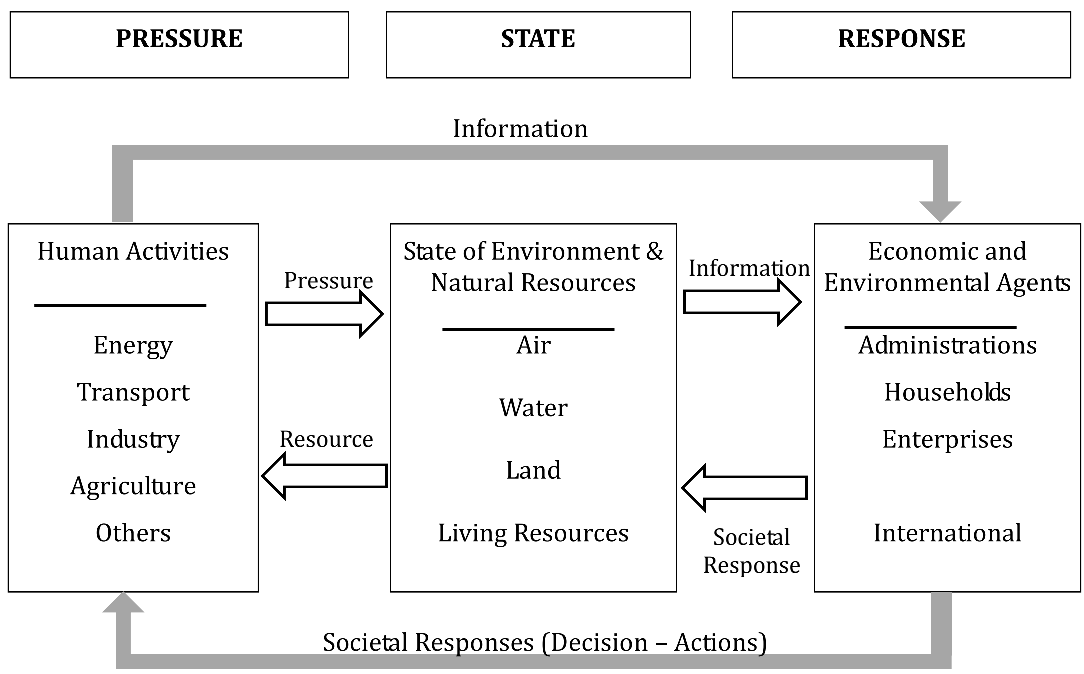
Pressure-State-Response (PSR) Framework

OECD (1993) first used the Pressure-State-Response (PSR) model for its work on environmental reporting, which was elaborated from Tony Friend and David Rapport's "stress-response" model, published in 1979. It is based on concept of causality of human activities on the environment and its impacts (for more details see Figure 2). Society responds to these changes through environmental, economic, social policies, and programs to prevent, reduce, or mitigate pressures and environmental damage, which in turn help to practice and promote the policies and programs towards sustainable

[5] System Dynamics was developed by Jay Forrester and his colleagues at the Massachusetts Institute of Technology by applying the concepts from feedback control theory to the study of industrial systems (Forrester 1961). Nowadays, this method is widely used in business, environmental, sustainable development, economy, and agricultural analysis.

development (Campbell et al., 1999)[6]. The PSR framework takes into consideration the relationships between the environmental and economic dimensions of sustainable development (OECD, 1993). Figure 2 is the core PSR model used by OECD for environmental performance reviews that explains the interactions among human, environmental, and economic indicators of sustainable development. Generally, the human activities depend on the state of environment and natural resources such as air, water, land, and other living resources, which give the pressure on natural environmental settings. The human activities also depends on the economic and environmental agents such as administrations (governments or private), households, enterprises and international communities which provide the societal responses to develop and expand basic human needs such as energy, transport, industry, agriculture, and others. Therefore, the timely response is very much necessary to maintain the existing state of environment and natural resources that will help to fulfill the needs of the present generation as well as maintaining the needs of the future generation.

Figure 2. Interactions among human, environmental, and economic indicators of sustainable development in PSR Framework



Source: OECD Environment Monographs No.83 (1993).

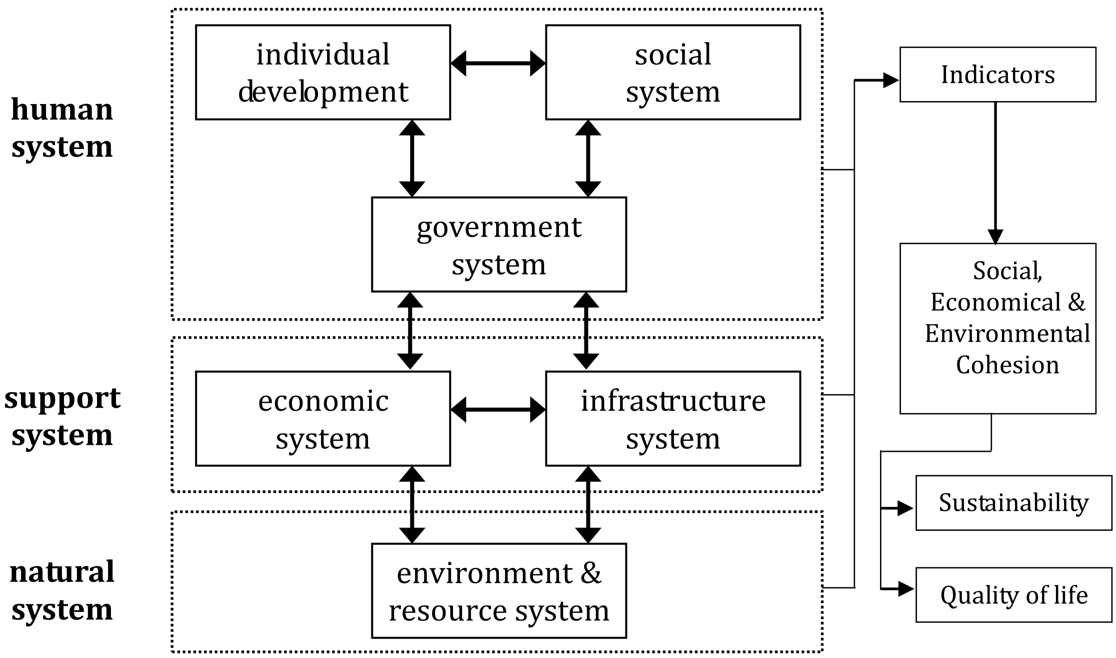
[6] Livestock and Environment Toolbox, Livestock, Environment and Development Initiative (LEAD), Animal Production and Health Division, FAO, 1999.

Later on, PSR framework has been updated and adopted by the United Nations Commission on Sustainable Development (UNCSD) in the form of Driving force – State – Response (DSR). Later on, it is updated in the Driving-force – Pressure – State – Impact-Response (DPSIR).DSR framework for sustainable development has been developed with the interplay of three major components; (i) driving force – human activities, processes and patterns that impact on sustainable development, (ii) state – the "state" of sustainable development, and (iii) response – policy options and other responses to change in sustainable development. In the DSR framework, "the term 'pressure' has been replaced by that of 'driving force' in order to accommodate more accurately the addition of social, economic, and institutional indicators, which allows to measure both positive and negative impacts on sustainable development" (Campbell et al., 1999). DSR framework has been widely accepted and used by academicians, development activists, and decision makers for sustainable development policy formulation and implementation.

Identification of Systems, Components and Models

The indicators for sustainable development are guided by the system components that help to structure the search for indicators. Based on the PSR model, the total system is generally composed of three components: pressure, state, and response, as explained in earlier sections. On this ground, this research paper is guided by Bossel's sustainable development model structure that is widely accepted and used by scholars to access the sustainable development indicators of different regions, countries, and the world. Figure 3 shows the conceptual sustainable development model in which the six major systems, namely the individual development, social system, infrastructure, economic system, and resource environment sectors are aggregated to the three major subsystems: human system, support system, and natural system (Bossel, 1999). The human system consists of individual development, social system, and government system. The individual development simply refers to the personality development or improving the quality of life, which are determined by the social indicators and the institutional capacity to deliver government services. Similarly, human system would have improvement only if the support system and natural system contribute positively. The support system is determined through the expansion of economic activities and level of infrastructure development. The infrastructure development also depends on the economic activities of the country, which ultimately contribute to the human system and natural system. The quality of life and sustainability indicators depend on the support system mechanisms mainly because it will determine the practices or the methods that an economy is using to expatiate the natural resources and environmental system. The complete system of human, support and natural provides the indicators of sustainable development. The interactions of sustainable development indicators provide social, economic, and environmental cohesion that gives the level of sustainability and quality of life in the particular study area. It also explains the relationships and interactions among the subsystems, orienteer, and indicators to achieve sustainable development.

Figure 3. Conceptual Sustainable Development model with three Systems



Source: Compiled from Bossel (1999) and Lektauers et al. (2010).

The figure shows the interaction among human, support, and natural systems in which the pressures have been created from human beings to the earth system in the form of individual or societal development. Those pressures are being the cause for the state of sustainable development. Therefore, the timely and proper policy measures are required to address the negative impacts of the human activities. This identification of the system and its components has given a framework to build the conceptual system dynamics model in this paper.

Measuring Sustainable Development

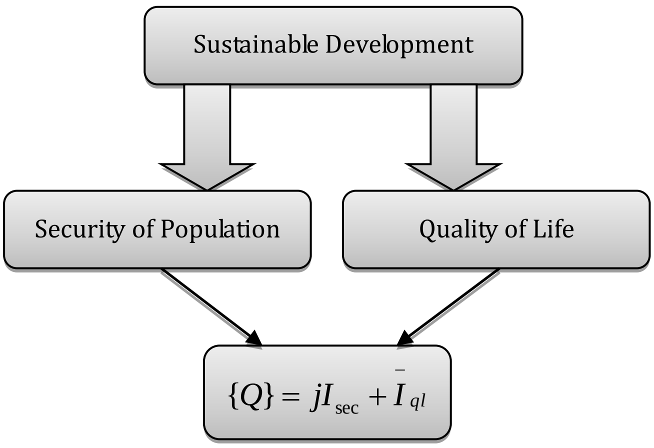
Zgurovsky developed the mathematical model to measure sustainable development with respect to quality of life and sustainability through harmonizing the three major components, human or social, economic, and ecological, identified from the DSR model. Zgurovsky (2009) expressed sustainable development mathematically by the sum of security of population (I_{sec}) and quality of life (I_{ql}), where the quality of life component of sustainable development consists of three dimensions: economic dimension (I_{ec}), ecological dimension (I_e), and social/institutional dimension (I_s). He further explained the mathematical model of sustainable development as follows:

The generalized sustainable development measure (index) may be presented by a quaternary {Q}, with the imaginary scalar part *j* (I_{sec}), describing the security of people and real vector part (I_{ql}),describing the quality of life in space with three dimensions: economic (I_{ec}), ecological (I_e),and social-institutional (I_s):

$$\{Q\} = jI_{\sec} + \bar{I}_{ql} \quad (1)$$

$j = \begin{cases} 1 \\ \sqrt{-1} \end{cases}$ for real positive values of $I_{sec} > 0$, for zero valuation of $I_{sec} = 0$ (conflict).

Figure 4. Quaternary Approach for Sustainable Development Representation



In this space, for each country, we have the sustainable development radius vector

(I_{sd}) with Euclidean norm[7]:

$$I_{sd} = \left\| \bar{I}_{sd} \right\| \sqrt{I_{ec}^2 + I_e^2 + I_s^2},$$

Which we define as sustainable development index (I_{sd}). The quality of life component (I_{ql}) is the projection vector (I_{sd}) of sustainable development on the ideal vector with coordinates (1;1;1).

$$I_{ql} = \sqrt{I_{ec}^2 + I_e^2 + I_s^2}.\cos(\alpha)$$

The angle (α) is defined as a degree of harmonization:

$$\alpha = arc\cos\left(\frac{I_{ec}^2 + I_e^2 + I_s^2}{\sqrt{3}\sqrt{I_{ec}^2 + I_e^2 + I_s^2}}\right), 0 \le \alpha \le \arccos\left(\frac{1}{\sqrt{3}}\right)$$

Zgurovsky's method of measuring sustainable development has provided the quantitative methodology, which also assists to clarify the conceptual system dynamic model. The quality of life index itself is a complex system that will affect economic, human, and ecological sub-systems dynamically.

Transferring Indicators in the Model

In light of the conceptual system dynamic model and Zgurovsky's model to measure sustainable development indicators as discussed in the earlier section, the components, indicators, and their relationships are developed to simulate system dynamic model. The quality of life index itself is complex to measure, but Zgurovsky's system helped to integrate the composite system of economic, human, and ecological sub-systems. Although sustainable development is very much a crosscutting issue and widely interconnected with social, economic, and environmental indicators, this paper has proposed the following indicators (for more details, see Figure 5) and their modeling connections, that are appropriate for measuring sustainable development, particularly on the quality of life and human development progress. Nevertheless, these indicators are only representative indicators to analyze the sustainable development indicators in any country in the world, which has a prospect to be changed based on the local and regional geo-political settings.

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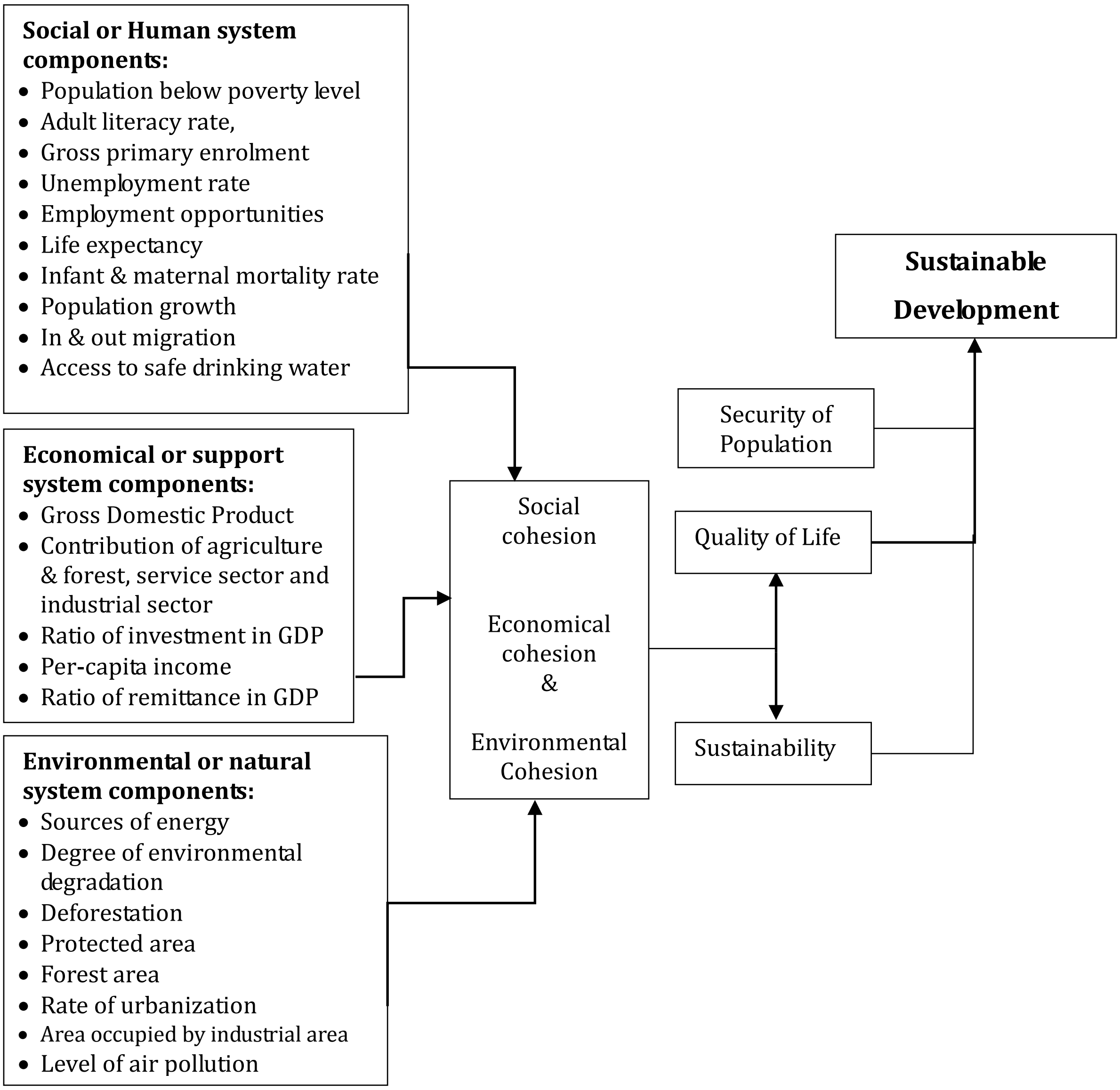
[7] The Euclidean norm of a complex number is the modulus or the absolute value of it.

Figure 5. Sustainable Development Model with Selected Indicators



The above indicators transferred in the sustainable development model are identified based on the framework developed by Bossel (1999) and the sustainable development agenda adopted by the government of Nepal. Further, the indicators are selected based on the level of quantification to measure the progress towards sustainable development outlined by the sustainable development agenda for Nepal. Additionally, these indicators have been chosen based on the priorities and importance given by the Government of Nepal on the Three Year Interim Plan (2007/08 – 2009/10) and Three Year Plan (2010/11-2012/13). These indicators are not the absolute indicators that we need to use in this particular model. The indicators' scope and types can be altered based on the research scope and the specificity of the country. The

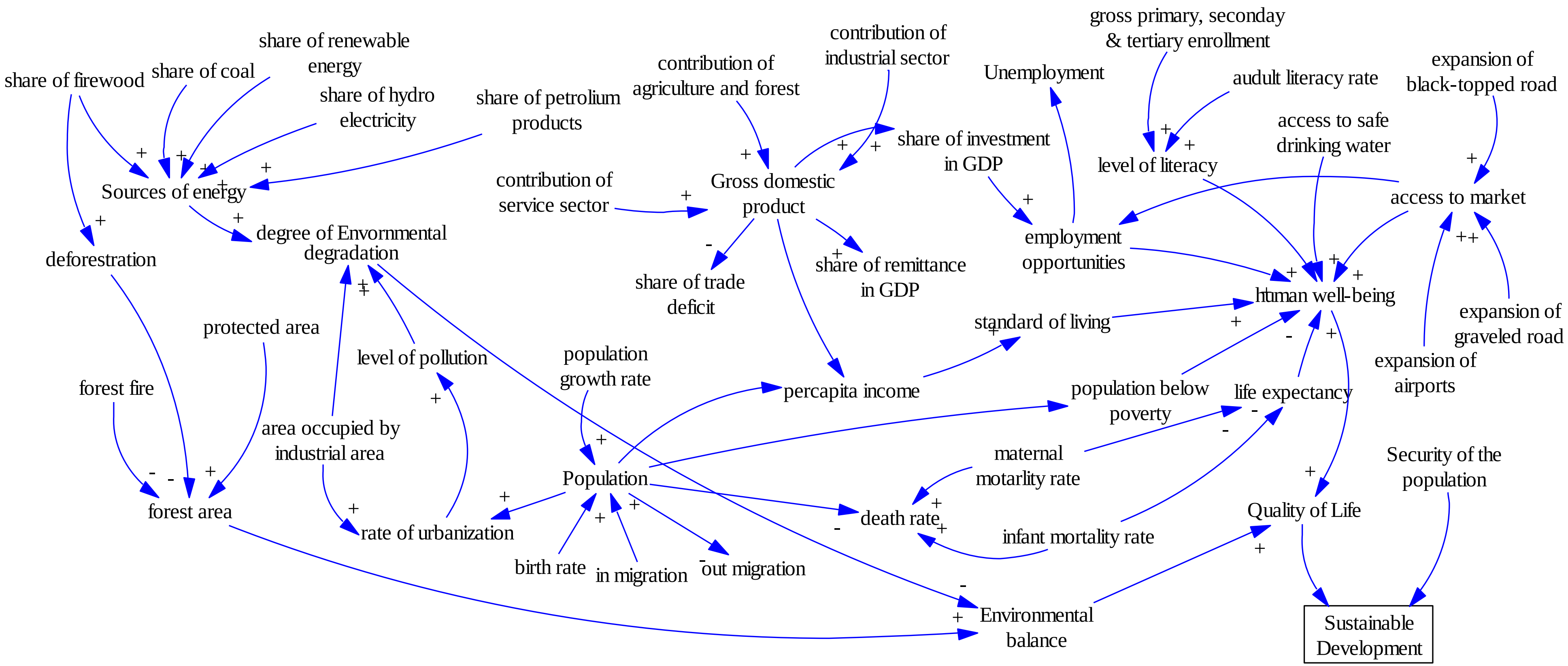
Government of Nepal as well as other developing countries should develop the enhanced data storage and distributing system to interconnect the data sets and forecast the progress on sustainable development precisely.

Mental Map / Casual Loop diagram of the Model

The casual loop is developed to expaln the possible cause and effect of the indicators, which is the foundation for the model programming and simualtion on system dynamic analysis. Figure 6 shows how the indicators are interrelated and how they affect the measurement of the overall objective of sustainabitlity and quality of life. This paper is centered on three structural dynamics: economy, environment, and social development. As proposed by Spangenber and Boniot. “Social sustainability is here understood as the combination of distributional justice (access to resources and education, distribution of income…) and the satisfaction of human needs (identity, health, comprehension)” (Spangenber and Boniot, 1998: 23).

The dynamics which are presented here to measure the quality of life and sustainabilityresembles the interrelated relationship among social, environmental and economic sustainabitlity.These dynamics are pushed by the casual loops among the indicators in Figure 6. There are four supporting loops driving the change in quality of life. The first loop explains how the environmental degradation is affected by more use of fossil fuels,whereas more use of renewable energy will decrease the environmental dagradation. This assumes that environmental balance is mantainted through decreased dagradation and increased forest areaor protected areas. The second supporting loop proposes that the gross domestic product will increase with the increase in agricultural, industrial, service, and remittance output. It further proposes that increase in the ratio of investment in Gross Domestic Product (GDP) will increase employment opportunities. The third reinforcing loop drives that the social wellbeing increases with increase in accessibility, safe drinking water, literarcy, life expectancy, employment opportunities, and percapita income. The fourth supporting loop is the effect of population on the environment through increased urbanization. The population will provide the backup to measure the progress towards quality of life and sustainability. Finally, sustainable development is supported by quality of lifeand security of the population. Each indicator is expected to contribute to its connected indicators either positively or negatively. Some of the indicators are expected to be constant.

Figure 6. Mental Map and Casual Loop of the Model



Note: This figure is developed from the sustainable development model in Figure 5, using Vensim™ 6.0[8]

[8] Vensim™ is a registered trademark of Ventana Systems, Inc.

Model hypothesis and expected relationship among Indicators

The casual loop (Figure 6) hypothesizes that the quality of life and sustainability will depend on the level of environmental degradation and human welfare. Indeed, it assumes that the only expansion on gross domestic product may not benefit daily life of the people. Therefore, this dynamic model calibrates with the following hypothesis to simulate the model and verify the relationship between the indicators. In this broader socio-economic system, each indicator has certain effects on other indicators that generate the feedback loop in the model. The feedback loop of the model rests on certain boundaries to produce the system thinking more rationally and logically. Therefore, this model is built based on the following assumptions or hypotheses among the indicators.

Table 1. Hypotheses and Expected Relationship among Indicators

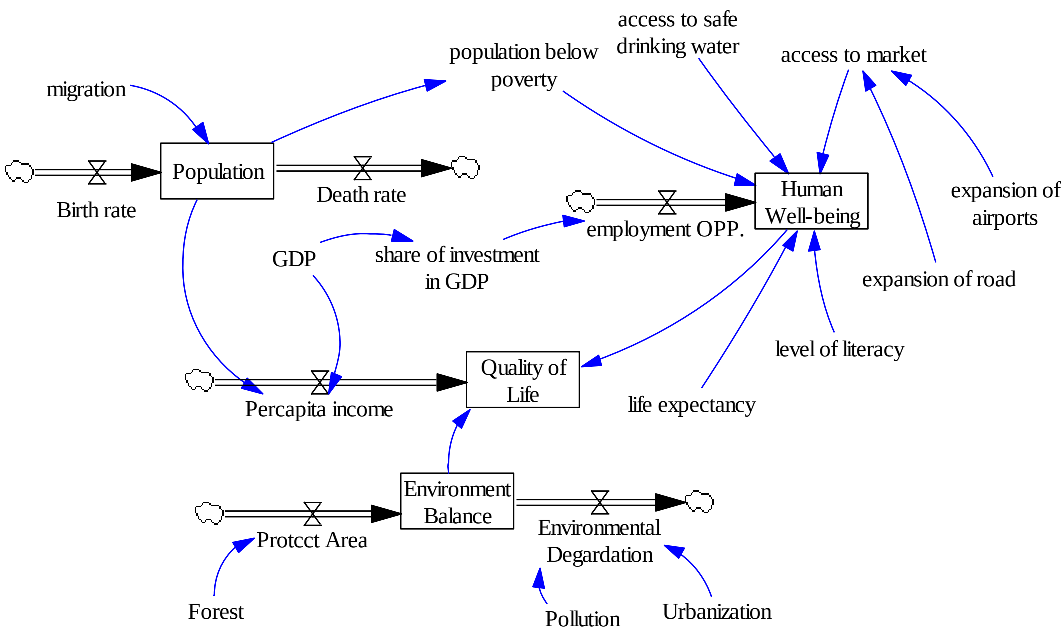
Broad Indicators	**Hypothesis and relationship**
Sources of energy	It is expected that the higher the use of firewood, coal, and petroleum products, the higher the possibility of environmental degradation.
Degree of environmental degradation	It is expected that there will be an increase in environmental degradation with more use of firewood, coal, fossil fuel (petroleum products), rate of urbanization, and area covered by industrial facilities. It means simply that the likelihood of environmental degradation depends on increase in industrial activities, urbanization, and certain types of energy usage.
Forest area	Forests and protected areas are expected to decrease with higher frequency of fire and deforestation.
Rate of urbanization	Increase in population, rate of urbanization, and in industrial activities will lead to rise in pollution level.
Gross Domestic product	GDP is expected to rise with increase in agriculture output, industrial output, service sector output, share of remittance, and decrease in trade deficit. Further, it is also assumed that the increase in share of investment in GDP will increase in employment opportunities.
Employment opportunities	Employment opportunities are expected to increase with decrease in unemployment, increase in share of investment in GDP, and access to market.

Access to market	Access to market is expected to increase with increase in length of tar or asphalt roads, graveled roads, and expansion of airports, which themselves help boost employment opportunities and human well-being.
Life expectancy	Life expectancy is expected to rise with decrease in maternal mortality and infant mortality rates, which themselves contribute positively for human well-being.
Human Well-being	Human well-being is expected to rise with increase in employment opportunities, level of literacy, access to safe drinking water, access to market, life expectancy, and standard of living. It is further assumed that population below poverty line will decrease with increase in human well-being.
Sustainability	Sustainability is expected to increase with decrease in environmental degradation and the maintenance of land covered by forest or protected areas.
Quality of life	Quality of life is expected to rise with increase in sustainability of environment and human well-being. It is assumed that sustainability contributes positively to quality of life.
Sustainable Development	It is expected that increase in quality of life and stable security will contribute to promote and maintain sustainable development. Security of Population can be calculated with Zgurovsky's (2009) formula, with Isec= 0 means conflict, and Isec= 1 means peace.

Stock and Flow Diagrams

The stock and flow diagram is the final stage of system dynamic modelling before simulating the model. It also provides the feedback structure on simulation. In this research also, the stock and flow diagram (Figure 7) is simplified from the casual loop diagram (Figure 6) to make it more practical and simple without losing the main spirit of model.

Figure 7. Simplified Stock and Flow diagrams of the model



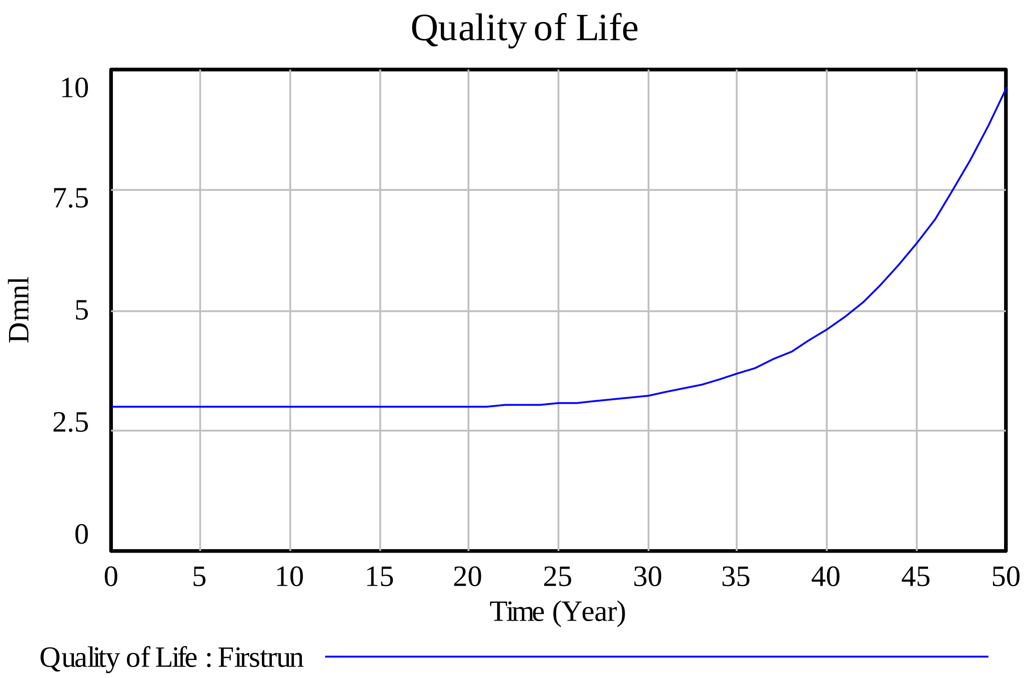
Source: Build on Vensim™ 6.0b based on the casual loop diagram of Figure 6

The conceptual system dynamic model is simplified in Figure 5.3 with maintaining the main spirit of the casual loop diagram and system dynamic model assumptions. The reasons behind dropping some variables are unavailability of the data and possible duplicity within the indicators while using the composite indicators. For example, the literacy indicator is already measured considering the school enrollment and its effects. Similarly, the life expectancy is a composite indicator of death rate, birth rate, child mortality, maternal mortality. The level of pollution is calculated based on the indicators of the EPI (air pollution effects on humans and ecosystem). Therefore, to simplify the model and simulate it, some of the indicators are added and some are dropped. The simplified stock and flow diagram (Figure 5.3) shows five stocks population, pollution, environmental balance, human wellbeing, and quality of life, which also explains their relationships in the model.

Results and Discussions of the Model

The model output is presented and analyzed broadly three categories 'Quality of Life', 'Environmental Balance', and 'Environmental degradation'. The simulation output or the results of the model are presented as below.

Figure 8. Change in Quality of Life



The Figure 8 presents the possible scenario of quality of life expansion based on the combined effects of environmental balance, human wellbeing, and per capita income indexes. The result is scaled between 0 and 10. The result shows that the change in quality of life in the beginning 10 years is very slow. According to the simulation, Quality of life increases rapidly after 20 years. It means that most researchers interpret this feedback structure is positive which shows the exponential growth pattern. Meanwhile, in the initial stage (0–20 years), the indicators are less effective to Quality of life.

Figure 9. Level of environmental balance

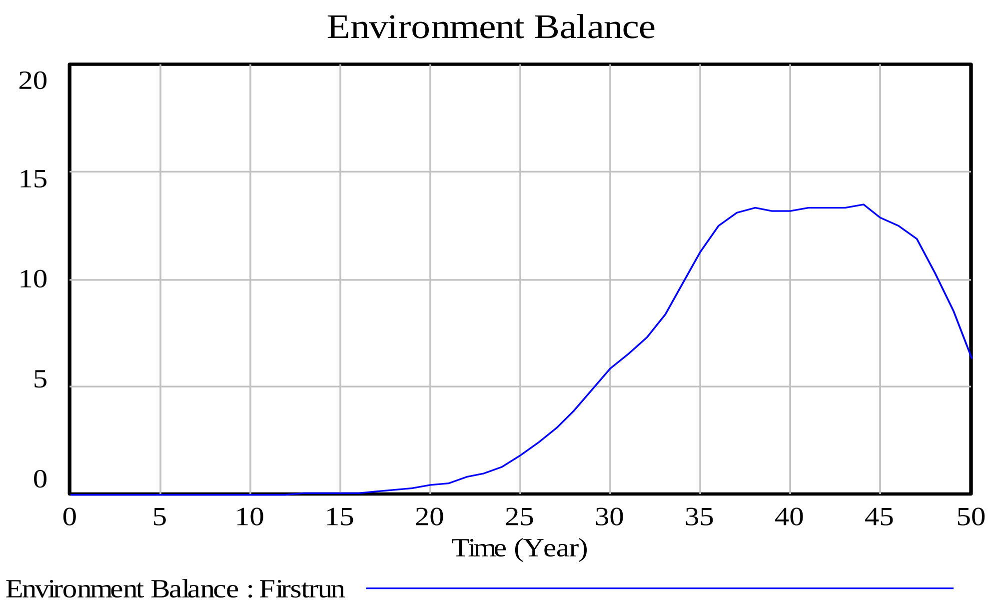
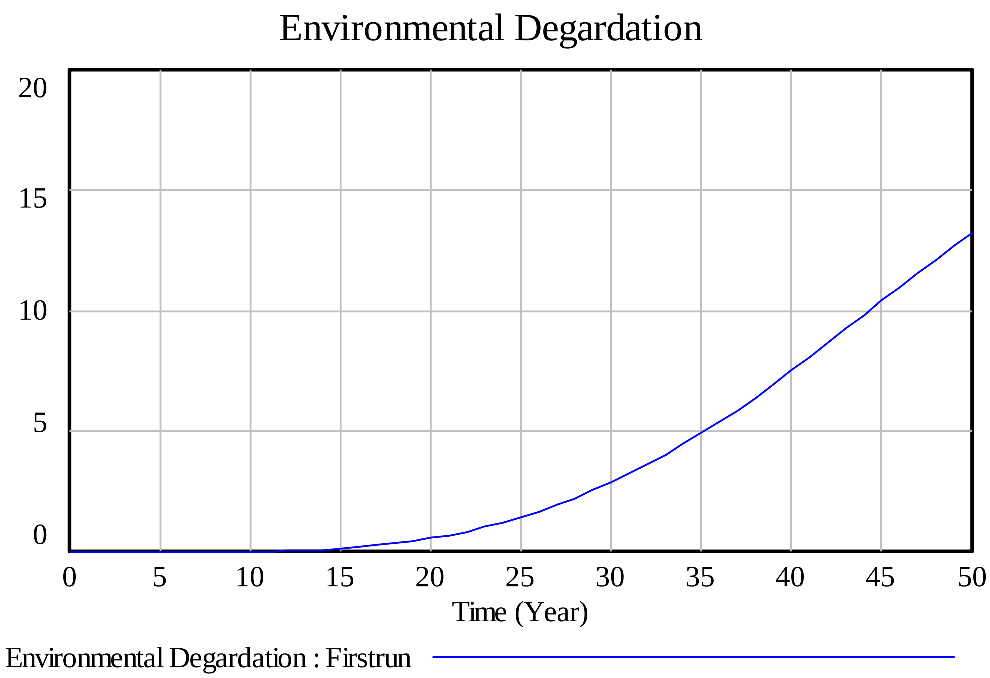


Figure 9 shows the environmental balance as assumed in model. The scale is set in 0 to 20. Initial stage (0-10) years, it shows almost zero level of balance that does not mean the environment is not balance. Indeed, it is showing the degree of harmonization for the future predictability only. The model output suggests that the existing forest area and protected area can maintain the environmental balance for about 40 years. The environmental balance may start to decline after 45 years. It is especially because of the raising pollution level and urbanization rate as outline in the model structure.

Figure 10. Degree of environmental degradation



The Figure 10 shows the degree of environmental degradation. The value is scaled between 0 and 20. It shows that in the initial stage the environment degradation is almost zero that does not mean there is not any environmental degradation in Nepal. Indeed, this model also harmonized for forecast. It shows that if in the beginning year the degree of environmental degradation assumes to be zero, the environment starts to grow exponentially after 20 years of modeling period.

Furthermore, it is difficult to coincide scales among Variables. The model output shows that 50 years prospects of quality of life and environmental balance a long with the environmental degradation in Nepal. Spangenberg and Bonniot, (1998) pointed out in their research "An economic system is environmentally sustainable only as long as the amount of resources utilized to generate welfare is permanently restricted to a size and a quality that does not overexploit the resources, or overburden the sinks, provided by the ecosphere"

(Spangenberg and Bonniot, 1998, p. 3). The simulation output exhibits that the sustainable development indicators show exponential growth in quality of life after 20 years of modeling period. Since the quality of life is composite indicator of per capita income, environmental balance, and human wellbeing, the government of Nepal need to expedite the investment not only in social sector also in the economic sector to harmonize the ripple effects of each sustainable indicator to maintain the quality of life and sustainability in the long run.

Policy Implications

The indicators of development are evolving as pointed out by Henderson (1994): "the goal of sustainable development is to clarify the confusion of *means* (i.e. the current obsession with economic growth) with truly evolutionary human development as the *ends* to be pursued within the ecological tolerances of the planet" (Henderson, 1994, p. 125). The government of Nepal should have a clear policy guidance and basic conceptual clarity to which way the state is moving to maintain the sustainability in terms of macroeconomic, social, and human development.

This research serves the theoretical framework to analyze the sustainable development indicators either in national or local scale. As pointed out by Initiative for System Dynamics in the Public Sector (ISDPS) in its website[9], the system dynamic model provides the dynamic view of policy problems, where "the system modelers can predict dynamic implications of policy, not forecast the values of quantities at a given time in the future." Therefore, this research serves as a policy tool to model and predict the future sustainability prospects of the quality of life and sustainable development indicators. It is identified that Nepal's mechanisms to promote sustainable development is still in weak stage as compared to the policy model prescribed by Baker (2006).

Indeed, this research can serve as the theoretical and practical framework to develop sustainable development policy in Nepal so that the different policies can be tested and exemplified to check the possible causes and outcomes of the sustainable development policies before implementation.

Conclusion

The indicators used in this dynamic model to measure the quality of life and sustainability satisfy the principles of driving pressure – state – response framework proposed and used by United Nations Division for Sustainable Development (UNDSD). Therefore, it creates the

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[9]http://www.isdps.org/System%20Dynamics.htm accessed on June 25 2013.

research platform for policy makers, development practitioners, and academics for further extension of modeling multiple indicators of social, economic, and environment together not only in Nepal but also in the rest of the world.

The system dynamic model used here is developed and explained based on the social, economic, and environmental cohesion of their indicators. The model output reflects just one possible scenario not exactly that will happen or can be compared with others rather it provides the broader future aspects of sustainable development. Indeed, the model results serve the future possibility of quality of life in Nepal based on the output that is received by simulating last 15 years data sets through the system dynamic. As the basic principle of the system dynamic modeling is that the model does not provide numerical forecasts, it exhibits possible behaviors of the indicators with change in time and subsequent variables. Therefore, this research can serve as the policy tool to analyze the behaviors of sustainable development indicators for the Nepalese policy makers, academicians, and researchers.

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