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Methodological and Conceptual Explorations in

Enhancing the Understanding of Watersheds

A Case of Lake Balaton Watershed, Hungary

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Author's declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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ABSTRACT OF THESIS submitted by:

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This topic for the thesis researchwas chosen with two purposes in mind: (a) to respond to a general concern about the impact of various disturbances on ecologies and societies in watershed areas, and (b) to respond to the need expressed by the stakeholders in the Lake Balaton region in Hungary to undertake further integrated research in the problems of the region. The two research questions involved developing a detailed and comprehensive system dynamics model at the conceptual level in two stages and using two research methods: (i) in the first stage, using secondary inputs from previous research based on the two research tools, viz., 'Scenario Planning' and 'Indicator and Measurement Systems', and (ii) in the second stage using primary data obtained through participatory system dynamics modelling methods.

The following are the four major outputs of this research effort: (i) the methodological procedure for developing a system dynamics model, using previous research based on the tools of indicator systems and scenario planning, (ii) a preliminary system dynamics model using previous research (iii) the methodological procedure for conducting sessions using the Participatory System Dynamics (PSD) modelling method, (iv) a complex, detailed conceptual system dynamics modelof the social-ecological system of the Lake Balaton watershed region, using PSD method.

It is suggested that, in taking this work ahead, the system dynamics model developed in this thesis should be quantified, simulated, and further enhanced in the future. The simulated model can also be used for developing an interactive, multi-purpose tool that could be used by various stakeholders, experts, citizens, and decision-makers for communication, awareness-building, negotiations, consensus-building and finally for decision-making.

Keywords: Social-Ecological Systems, System Dynamics Modelling, Participatory System Dynamics Methods, Indicator Systems, Scenario Planning, Watersheds, Tourism, LakeBalaton

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Chapter 1:Introduction

1.1 Watershed Ecosystems and Human Societies

River valleys are said to be cradles of human civilizations and the history of humankind is said to be dominated by the riparian civilizations (Sharma and Sharma 1997; Dudgeon 2000). The riparian civilizations are founded on riparian ecosystems that flourish in the watershed zones (Oxbow River & Stream Restoration 2008). The term 'watershed' is defined by John Wesley Powell as: "that area of land, a bounded hydrologic system, within which all living things are inextricably linked by their common water course and where, as humans settled, simple logic demanded that they become part of a community" (US EPA n.d.). The watersheds are of varying sizes from small watersheds to vast valleys of big rivers.

Watershed ecosystems provide a wide variety of goods and services to human societies (Nilsson and Renöfält n.d.). The benefits offered by the watershed ecosystems are of three major categories: "water for human needs (consumption and sanitation), goods other than water, such as food and fibre (e.g., fish and fuel wood), and non-extractive benefits such as recreation, transportation, self-purification, and energy" (Nilsson and Renöfält n.d.). As a result, all watershed based human societies and even the urban societies of this era are dependent ultimately on the health of ecosystems (Visalli 2013).

The watershed-dwelling human societies possess a long history of building, changing and redesigning structures and flows in natural water channels. Many of these alterations led to changes in physico-chemical aspects. Increasing human intervention has degraded natural freshwater ecosystems, leading to radical alterations in watershed and ecosystem conditions (Nilsson and Renöfält n.d.). Even the modern societies, with all the scientific knowledgebase they possess, neglected their rivers and streams, forgetting that they are part of the "infinite network of interconnections in the ecosystem" (Oxbow River & Stream Restoration

2008).As a result, as per the Millennium Ecosystem Assessment 2005, the increasing human use of freshwater and the degradation of freshwater quality have led human societies to a challenging situation, where shortage of safe water is likely to inhibit food production, ecosystem function, and systems of urban water supply (Nilsson and Renöfält n.d.).

1.2. Need for Sophisticated Conceptual and Research Tools

Such challenges require a serious look at the manners in which water ways, water bodies, watersheds, and the ecosystems in the watersheds are treated and used. It is high time that we understand and treat with ultimate care the "ecosystem which we impact daily and which we can have an active role in understanding, appreciating and being a part(Oxbow River & Stream Restoration 2008). At the core, these challenges involve finding ways to satisfy the demands of both humans and nature in the watersheds, without inhibiting the growth of either (Nilsson and Renöfält n.d.). Considering the complexity and urgency of this challenge, the researchers and academics have been exploring new ways of thinking, and of improving the governance and management of watersheds (Nilsson and Renöfält n.d.). In this endeavour, many new methodological or research tools and conceptual frameworks are increasingly used. These new research or methodological tools include the Indicator and Measurement Systems, Scenario Planning, Environmental Modeling, Systems Dynamics, and Agent-based Modeling(Horvath 2011; Molnár et al. n.d.). The conceptual frameworks tools that are currently explored include those around the concepts and themes such as environmental flows, water-energy-food nexus, socio-ecological systems, and resilience(Nilsson and Renöfält n.d.; Folke et al. 2005).

1.3 Introduction to Key Conceptual and Research Tools

1.3.1 Concept of Socio-Ecological Systems

For the current research, the watershed regions around the water bodies are of particular interest. Across the world, various watershed regions are facing an acute water crisis

(Vörösmarty et al. 2000). This is the primary concern for this research, especially the threats faced by both, ecological systems as well as communities in these watershed regions. The concept of 'Social-Ecological Systems' (or SES's) helps to bring together these two elements of the reality in watersheds. From the system perspective, the concept of SES focuses on complex and multifaceted "connections between the bio-geo-chemical processes in the ecological system and related actors and drivers in the socio-economic system"(Jahn et al. n.d.). In the era marked by fast and often cataclysmic environmental, social, or political disturbances, the stability and sustainability of SES's are naturally the main concerns.

1.3.2 Indicator and Measurement Systems

As per one definition, "an indicator quantifies and simplifies phenomena and helps us understand complex realities. Indicators are aggregates of raw and processed data but they can be further aggregated to form complex indices" (Baldi n.d.). The indicator system is seen as made of the hierarchy of four levels of concepts: (a) Principles: "a fundamental truth or law as the basis of reasoning or action," (b) Criterion: "a principle or standard that a thing is judged by" (c) Indicator: "an indicator is any variable or component used to infer the status of a particular criterion," (d) Verifier: "Data or information that enhances the specificity or the ease of assessment of an indicator" (CIFOR 1999; Hart 2008). Utility or importance of indicators could be summed up in the remark by M. Hart: "What gets measured, gets managed and what is not measured is often ignored" (Hart 2008).

1.3.3 Scenario Planning

Scenarios are essentially stories, narrations, or descriptions of the future states of affairs, while Scenario Planning is described as the process "to craft a number of diverging stories" (Wikipedia 2013; Martin Borjesson n.d.). It is seen as a method for learning about the future by understanding the nature and impact of the most uncertain and important driving forces affecting our world. Thus, it involve: "blending the known and the unknown into a limited number of internally consistent views of the future that span a very wide range of possibilities" (Wikipedia 2013).

It needs to be kept in mind that Scenario Planning is not a tool to predict the future; rather it is a tool for creating and assessing "multiple futures". The scenarios should be used to draw broad learning about the uncertainties involved in the future, extract guidelines for possible and required "robust" strategic adjustments in the course of actions, and even "rehearse our responses to those possible futures"(Wikipedia 2013; Wilkinson n.d.).

1.3.4 System Dynamics Modelling

Models are a substitute for the reality, when we cannot experiment with the reality to understand the implications of our actions. Often, modeling forces researchers and practitioners "to re-examine their intuitive understanding of the system"(Ford 1999). Modeling can also help in dealing with the 'Law of Unexpected Consequences', where actions of people lead to unexpected, unanticipated, or unintended side-effects(Norton n.d.). This law is seen rooted in our tendency to have an event-based worldview, and to think about experiences and the reality as a linear, cause-and-effect series of events, that seem to be closely linked in time and space (Sterman 2000).

There are often called feedbacks. As Sterman explains, they are "result of our actions and define the situation we face in the future"; these feedbacks lead to the unintended consequences (Sterman 2000). Thus, taking these feedbacks into account is very critical. System dynamics modeling is one of the ways to incorporate feedbacks in the analysis and is an effective method to enhance learning about complex systems. Dynamic models are special, as they help us think about how the system changes over a period of time (Ford 1999). It needs to be noted that system dynamics models are not predictive models but are meant more for learning and understanding how the system behaves and the patterns underlying the behavior. It is pointed out that a single simulation of the system dynamics model will not give all the answers we require, but patterns emerging from a comparison of multiple simulations can teach us a lot about the system (Ford 1999). At the end, it is often stressed that modeling is an iterative process.

1.3.5 Participatory System Dynamics Methods

There are many methods and tools used for eliciting, building, and analyzing system dynamics models, which are discussed in detail in the next chapter. Participatory System Dynamics (PSD) is one of the methods for eliciting mental models and building system dynamics model. It includes any approach for engaging—in different stages of model building and to varying degrees—stakeholders in the analysis of the problem using the tool of system dynamics modeling(Stave 2010). Further, PSD methods are also seen as useful for "building shared ownership of the analysis, problem, system description, and solutions or a shared understanding of the trade-offs among different decisions*"*(Stave 2010).

There are different methods for PSD modeling. While Group Model Building is the most practiced, the more relevant method for this research is the Community Driven Systems Dynamics (CDSD). These are discussed and critiqued in detail, in the next chapter.

1.4 The Reality of the Balaton Region

As mentioned before, human societies located in watersheds and thriving on a variety of water-related services provided by water bodies and water-channels have very critical relationships with the water bodies. This is also witnessed in the case of human settlements located in the watershed area of the Lake Balaton.

Lake Balaton is one of the biggest lakes in Europe, located in the central European country of Hungary. The lake has been drawing a large number of tourists for many decades due to its pleasant summer weather and natural beauty. The lake is very shallow for its size and there has been a concern over the fluctuation and decrease in the level of water in the Lake Balaton, as it has serious implications for the ecology of the region as well as the economy and society in the region. The concern over the water level assumed grave proportion in the initial years of the 21st century, when, due to consecutive exceptionally dry years, the water level in the lake went down to the all time low. The roots of this situation have been traced to the broader processes related to global climatic changes. The severe fall in the water level in the lake during the years between 2000 to 2004, raised concern over the vulnerability of the region to the fluctuating climatic trends and especially over feasibility of tourism—which is the main source of economic activity in the region—in the short and long terms (Pinter et al. 2008), (Horvath 2011).

The concern has been addressed through a variety of measures, technical as well as administrative and governance measures (Lake Balaton Development Council n.d.). The concern has also given rise to research efforts aimed at understanding the complex relationships between, on one hand, the climatic factors, and, on the other hand, the ecology, the economy, and the society in the region. Various academic, research and multilateral agencies have undertaken significant efforts for research in the Balaton region using the research or methodological tools of Indicator Systems (IS) and Scenario Planning (SP)(Pinter et al. 2008), (Horvath 2011), (Bizikova and Pinter 2009),(Varga n.d.), (Lake Balaton Development Council n.d.). However, considering the expected continuation of the fluctuating trends in the climatic factors, the stakeholders in the region feel an urgent need for more research in economic, ecological, and social processes in the Balaton region. The research should, more specifically, enhance the understanding of the effect of fluctuating climatic factors on ecology, economy, and society in the watershed region around the Lake Balaton.

It needs to be noted that many watershed areas across the world are experiencing similar fluctuating climatic, ecological, and economic trends which are posing threats—of varying nature and degrees—to the economies, societies, and ecological systems in these regions. Thus, the understanding gained through this research will be useful and relevant to many similarly situated watersheds across the world.

1.5 Articulating the Focus Problem and Research Questions

Thus, the challenges, referred to in the earlier section, of finding ways to ensure synergy in a mutual coexistence of ecosystems and human societies in watersheds across the world are also manifesting in the Lake Balaton watershed region in the form of the specific concern over the impact of fluctuating climatic factors on ecology, economy, and society. In view of the complexity and urgency of these challenges, use of more sophisticated conceptual and research tools was found to be necessary. This also holds true in the case of the Lake Balaton region, where the need for more research was felt in order to deal effectively with the concern over impacts of fluctuating climatic factors. Various conceptual and methodological tools that were briefly introduced in the previous section would be potentially helpful for enhancing the understanding of and responding to the concerns of stakeholder in the Lake Balaton region. In this context, the Focus Problem for this research was articulated in the following manner.

1. How to effectively use the research tools (such as SP, CIS, SD, and PSD) that are found to be relevant for understanding and responding to the concerns related to the current situation in the SES of the Balaton watershed region?

This focus problem was further articulated to arrive at more specific and relevant research questions by drawing from the discussion in the previous sections. The ecology, economy, and society in the Balaton region, together, can be seen as forming the socio-ecological system or SES of the Lake Balaton region. The concern over the impacts of fluctuating climatic factors on the SES of Balaton region can be expressed in terms of the concern over the sustainability of the Balaton SES. Thus, the focus problem can be understood as involving the core task of understanding the behavior of the socio-ecological system of the Lake Balaton region, in view of the fluctuating climatic factors.

The brief discussion on research or methodological tools in the previous section indicates that the tool of system dynamics modeling is appropriate for understanding the behavior of the complex, non-liner systems like socio-ecological systems. This is because such systems, comprising many critical feedback loops, render usual research and analysis tools inadequate and inappropriate(Ostrom 2007). Thus, the task of understanding the behavior of the SES of Balaton Lake region essentially involves building a system dynamics model of this SES. Further, the Participatory System Dynamics (PSD) methods appear to be appropriate for building SD models of the socio-ecological systems.

As mentioned before significant research had been conducted on the problems faced by the Lake Balaton region using the research or methodological tools of Indicator Systems (IS) and Scenario Planning (SP). It is possible to draw a variety of inputs from this previous research. However, considering the complexity involved in the Balaton SES, the utility of secondary data from the previous research was seen as limited.

Hence, it was envisaged that the inputs from the previous research would help create the first basic version of the model. Using this basic model as a broad basis, a detailed conceptual model could then be built using the PSD methods. Based on this discussion, the Research Questions for this research were defined as the following:

1. What are the inputs from the previous research conducted using the tools of SP and Indicator Systems that can be used to create a conceptual system dynamics model, as a base for understanding the Balaton SES?
2. What inputs from sessions with representatives of stakeholders based on the Participatory System Dynamics methods can be used to build a pilot-level conceptual system dynamics model of the Balaton SES using the PSD method?

1.6 Methodology

The methodology adopted for this research involved the use of different research tools as mentioned before. In addition, two special-purpose procedures were developed to respond to the research questions, which can be seen as methodological innovations.

The research began with a comprehensive review and analysis of the literature on the four research methods and methodological tools of interest for this research: (a) Scenario Planning (SP), (b) Indicator Systems (IS), (c) Systems Dynamics Modeling (SDM), and (d) Participatory System Dynamics (PSD) Modeling Methods. The literature review also covered the literature related to the concept of SES. As the main focus of the research was the concept about situation in the Balaton region, diverse literature on Balaton region was also reviewed.

The first research question required building a system dynamics model using the secondary data available in the knowledge-base created through previous research conducted using the tools of SP and IS. A methodological procedure was developed in the course of research to operationalize such cross-method learning.

Finally, a large portion of the time and resources was expended in collecting and using primary data through PSD methods for building a detailed conceptual model of the Balaton SES, which was based on the procedures adopted in system dynamics modeling.

The PSD exercises were conducted in three steps. The first step involved individual interactions with the representatives of key stakeholders for building the first version of their respective mental models. The second step involved the second round of individual sessions for verification, correction and quantification of the model. The third step comprised the joint exercise with a group of participants of individual PSD sessions for verification of the model and assessment of utility of the model.

1.7 Audience and Implications

The first set of audiences for this research is the stakeholders in the socio-ecological system of the Lake Balaton watershed region in general. More specifically, Lake Balaton Development Coordination Agency, is the primarily audience from the group of stakeholders. The stakeholders can make use the output of this research for better understanding of the system. The pilot level causal model developed can be later on simulated and used as a base for an interactive tool. This interactive tool is envisaged to be a tool for communication, awareness building, negotiation, or decision-making.

The thesis research will also be addressed to members of the academic community, especially those interested in the concepts and research tools explored and used in this research. The research—especially the use of SD modeling for SES—is expected to be relevant for the practitioners working in the related fields such as lake conservation and nature-based tourism.

1.8 Limitations

This research is conducted for writing a thesis for the master's program, which brings in certain limitations on available time, resources, and expertise. These factors significantly limit the scope and depth of the research on the chosen topic that has multiple and complex dimensions. Another source of limitations faced by the research effort was the language barrier. The researcher does not know the Hungarian language and hence there were limitations on drawing inputs from both the sources used, the literature and interactions with the local stakeholders. These two limitations put restrictions on the data that can be obtained for building the model. Further, building a model of such a multidimensional complex socio-ecological system requires a team of expert from different disciplines with a high level of expertise and experience. This single-handed effort by a master's level student is certainly inadequate for the tall task. Hence, the objective envisaged for the research was kept limited to developing a pilot-level, conceptual model of the system, which can be used as a foundation for developing a full scale, quantified, simulated model supporting the multipurpose tool for diverse stakeholders for different purposes.

1.9 Outline

After this introductory chapter, the second chapter of this report presents, in its first four sections, the review and analysis of the literature on the concept of social-ecological systems (SES) and the three main research tools, viz., Scenario Planning (SP), Indicator Systems (IS), and System Dynamics Modeling (SDM). In order to prepare for answering the first research question, the fifth section develops a methodological procedure for building system dynamics model using the knowledge base created during the research using the tools of SP and IS. In the last and sixth section, the review and analysis of the literature on different methods of building system dynamics modeling are presented.

The third chapter is entirely devoted to the discussion on the methodological aspects of the research. In the first section, the research design developed in the introductory chapter is further elaborated by articulating the research objectives for each of the research questions identified before. The second sectionadapts the methodological procedure builtin the fifth section of the previous chapter. The third section, first, presents the methodological procedure for conducting sessions based on Participatory System Dynamics (PSD) method, using the discussion in the last section of the previous chapter. In its later part, this section also reports on the revisions and adaptations that were made in the procedure at the time of its actual use during this research on Balaton.

After this preparation, the fourth chapter is devoted entirely to reporting on the response to the first research question. In the first section, it presents the review and analysis of the literature on the problems and different processes pertaining to the SES of the Balaton region. In the second section, a system dynamics model of the Balaton SES is presented in terms of description of the causal linkages and discussion on the causal loops in three causal diagrams. This model is developed using the procedure suggested in the second section of the third chapter. The model is called here as the base-level model and helped the researcher in diverse ways to respond to the second research question.

The fifth chapter is devoted to answering the second research question. It is the mainstay of this report. It presents the system dynamics model of the social-ecological system (SES) of the Lake Balaton region, using the inputs received from the interactive sessions based on PSD method. The sessions are conducted using the procedure presented in the third sub-section of the third chapter. In essence, it is a detailed conceptual model of complex intertwined SES; and called here as the pilot-level model, considering its limitations. The first sectionof the chapter introduces the overall structure of the model, which is composed of two components: the meta-model and the eight layers. The eight layers represent eight critical themes. The structure and purpose of the meta-model is discussed in the second section. Drawing from the primary data collected through PSD sessions, the subsequent eight sections present the eight layers of the model, each containing: causal linkages within and across the layers, causal loop diagrams, feedback loops, stock and flow structures, and suggested interventions.

The last and sixth chapter is the concluding chapter. In its first section, it briefly presents the achievements made during the research, while the second section presents the lacunas and gaps in the efforts for responding to the two research questions. The last and third section presents the ideas about possible work in the future. It has two major suggestions: (i) further development of the conceptual model through its quantification, simulation, testing, and expansion; (ii) development of an interactive and multi-purpose tool, built on the simulated model, for stakeholders and decision makers.

Chapter 2:Methodological and Conceptual Explorations and Analysis

The main objective of this chapter is to present the review and analysis of the literature on five critical elements of this research, one of which is a concept and the other four are research or methodological tools. These include the concept of social-ecological systems (or SES), and the four tools of: (i) Scenario Planning (SP), (ii) Indicator and Measurement (or Criteria and Indicator) Systems (IMS), (iii) System Dynamics Modeling (SDM), and (iv) Participatory System Dynamics (PSD) Modeling Methods. The last section presents a comparative analysis of three of these tools—SP, IMS, and SDM—which draws out possible connections among the procedures involved in application of these three tools.

2.1 Understanding the Concept of Socio-Ecological Systems

2.1.1 Definitions and Explanations of the Term

The term socio-ecological systems (or SES) have been defined in the literature in somewhat similar manner, though there are some nuanced variations. Similar term like Social-ecological systems has also been used (Lade et al. 2013; Walker, B., et al. 2004; Folke et al. 2005).

Resilience Alliance view SES as: "systems—in which cultural, political, social, economic, ecological, technological, etc. components interact". Hence, SES are defined as "integrated system of ecosystems and human society with reciprocal feedback and interdependence". The use of the phrase is justified as it helps focus on the "on the interactions between the (non- human) natural world and the human-constructed world"(Resilience Alliance 2007).

As mentioned before, one researcher defined the term as: "Socio-Ecological systems (SES) are complex, adaptive systems, which underline the connections between the bio-geo-chemical processes in the ecological system and related actors and drives in the socio-economic system" (Jahn et al. n.d.). The concept of SES is said to have emerged out of the realization that:

> "simple, linear understanding of ecology and society are not adequate in the face of the enhanced understanding of the different ways in which they interact with each other andrespond to thesolutions proposed and applied to resolve social and environmental problems" (Berkes E.F., Cloding, and Folke 2003).

Thus, the spheres of society and ecology are intertwined in an intricate mannerly, which are akin to the characteristics of complex adaptive systems (Berkes E.F., Cloding, and Folke 2003; Folke 2006).

Complex systems are systems, are process- dependent organic systems, which cannot be seen as "deterministic, predictable and mechanistic, but as with feedbacks among multiple scales that allow these systems to self-organize" (Folke 2006). The complex adaptive systems (CAS) are distinguished by the following defining characteristics: nonlinearity, uncertainty, emergence, scale, hierarchical, and self-organizations (Berkes E.F., Cloding, and Folke 2003). While the characteristics of nonlinearity, uncertainty, and emergence distinguish them as complex systems (as against simple systems), the features of self-organization make them as adaptive.To provide brief explanation here, nonlinearity "essentially means the existence of more than one state of equilibrium for the system" while emergent properties are those, which "cannot be predicted or understood from examination of parts (of the system)" (Berkes E.F., Cloding, and Folke 2003). Feedback mechanisms make self-organization possible (Berkes E.F., Cloding, and Folke 2003).

Janssen and Ostrom focus on the 'social' sphere of SES's and emphasize on the role played by its two key elements: individuals strategies (deployed for attaining their goals) and institutional rules (which includes formal and informal rules). They claim that these two elements interact to shape the behavior of the system(Janssen and Ostrom 2006).

2.1.2 Decomposing Socio-Ecological Systems

Ostrom, in another paper, presents the 'Nested Framework for Analyzing Interactions and Outcomes of Linked Social-Ecological Systems.' She describes SES as "complex, multivariable, non-linear, cross-scale, and changing" (Ostrom 2007). Asserting that it is possible to partially decompose the structure of complex systems, she visualizes them as being arranged in levels, and "the elements at each lower level being subdivisions of the elements at the level above"(Ostrom 2007). At the broadest conceptual level, she suggests a general framework or a conceptual map comprising of eight main elements. These include: (i) a resource system (e.g., fishery, lake, grazing area), (ii) the resource units produced by that system (e.g., fish, water, fodder), (iii)the users of that system, (iv) the governance system, (v) interactions among Resource Systems and Resource Units, (vi) Outcomes of these interactions, (vii) Related Ecosystems, (viii) Social, Economic, and Political Settings. She proposes that each of the eight broad variables can be unpacked to identify variables at the second, third, and even fourth "conceptual tiers" (Ostrom 2007).It is envisaged that there could be interactions and interrelations among variables across these different tiers.

2.1.3 Concept of Socio-Ecological Systems: Relevance for this Research

As mentioned before, human societies, throughout the history of human kind, have been critically dependent on the surrounding ecological systems, while these ecological systems have undergone changes and evolution as result of interventions of human societies. This mutual interdependence involves a large number of interrelationships and interactions between the human societies and the surrounding ecological systems. This situation is captured most effectively by the concept of 'Socio-Ecological Systems' (or SESs), which, as mentioned before, from system perspective, focuses on complex and multifaceted "connections between the bio-geo-chemical processes in the ecological system and related actors and drives in the socio-economic system"(Jahn et al. n.d.)Further, according to Carpenter et al., lake regions are one of the most appropriate situations for using the concept of social-ecological systems (Janssen and Ostrom 2006).

When viewed from the system's perspective, the expected 'function' of any SES could be defined as to make contribution to sustainable development, more specifically, economic development, social equity, and ecological health of the region or in this context the of the watersheds. However, in the current situation, the abovementioned function of the SESs—i.e., of contributing to sustainable development—is seen to be under serious threat from different disturbances or perturbations (Ostrom 2007). These disturbances—which often lead to the stress on availability, affordability, access, security, and / or quality of water services—are both, endogenous and external in nature, and include, for example, climate change, spatial growth and shift, natural disaster, or political strife (Pollard, Biggs, and Toit 2008).

The concept of 'sustainability' has been analyzed and reinterpreted in many ways. In relation to the SES, CSIR presents an interesting schema for understanding sustainability, which his presented in Figure 2.1 (Trotter n.d.)

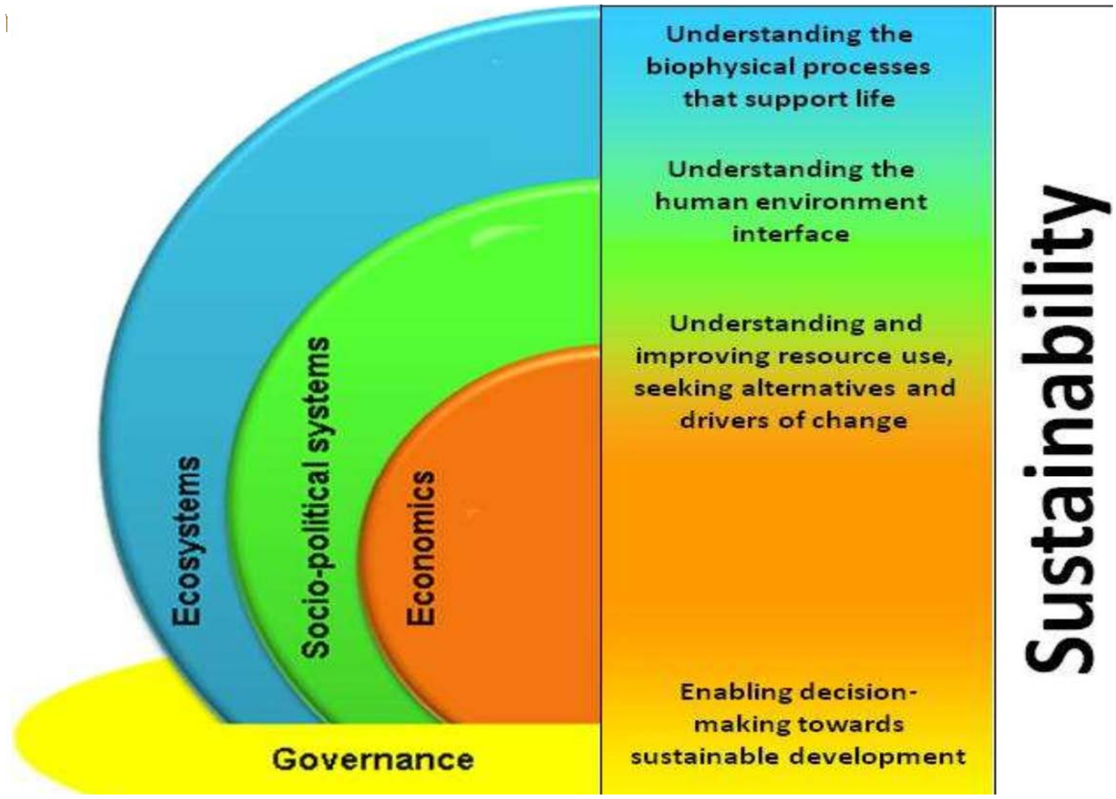

Figure 2.1: Sustainability of Socio-Ecological Systems(Trotter n.d.)

2.1.4 Utility of Chosen Research Tools to Understand SES

As mentioned before, the SESs are seen as a good example of complex adaptive systems (CAS) demonstrating characteristics of nonlinearity, uncertainty, emergence, scale, hierarchy, and self-organizations. It is also pointed out that the simple, linear, predictive tools not only fail to understand such systems, but the solutions emerging from such tools are often counter-productive for the resolution of the problems of such CAS " (Ostrom 2007). In contrast, the tool of SP is designed precisely to deal with uncertainties in future, while the tool of SDM is capable of dealing with the characteristics like nonlinearity, emergence, and self-organization.

2.2. Understanding Research Tool of Scenario Planning

2.2.1 What are Scenarios?

Scenario Planning is seen as a tool or method for learning about future states of affairs, and also as "a disciplined method for imagining possible futures"(Martin Borjesson n.d.). It is a method for learning about the future by understanding the nature and impact of the most uncertain and important driving forces affecting our world. Scenarios are essentially stories, narration, or description of the future state of affairs, while Scenario Planning is described as the process "to craft a number of diverging stories" (Martin Borjesson n.d.; Schoemaker Paul JH 1995)

The method is said to be especially useful when the future is riddled with uncertainty (Wilkinson n.d.). There are some essential attributes and components of their definition. Apart from the attribute that the scenarios are narration or stories, the most salient feature of scenario are the two main components: "(a) things we believe we know something about and (b) elements we consider uncertain or unknowable" (Schoemaker Paul JH 1995). The known things are seen as part of the trends, which might continue in future. In most cases, the trends do include the problematic tendencies in the current situation, which are expected to continue or aggravate in future.

The second components are uncertainties or indeterminable. An attempt is made to understand the uncertainties in terms of the underlying driving forces, which will result in diverging possibilities for future. In other words, "trends cast the past forward, recognizing that our world possesses considerable momentum and continuity", and thus, the art of scenario planning is said to involve: "blending the known and the unknown into a limited number of internally consistent views of the future that span a very wide range of possibilities" (Wikipedia 2013)

2.2.2 Process of Developing Scenarios

Various authors provide somewhat similar processes or procedures for developing scenarios (Martin Borjesson n.d.; Wilkinson n.d.; Schoemaker Paul JH 1995; Bradfield et al. 2005)The processes and procedures provided by different authors could be used to develop the following procedure.

- The first step is identification of the focal issue or decision, which are to be used as a "test of relevance."
- This is to be followed by definition of the scope of the exercise including the time frame and scope of analysis.
- The next step then is identification of the major stakeholders, their current roles, interests, power positions, and possible changes in all these over time and the underlying reasons.
- The next step is identification of the "Primary Driving Forces", which will shape different version of future. Some of these are outside our control or predetermined and they will feature in all the futures. Some authors call these simply as trends.
- This is to be followed by identification of critical uncertainties. They are uncertainties as they are difficult to predict and are critical because they are "key to the focal issue".
- The next step is to organize these critical uncertainties into two or three internally related groups and present them along two or three axes. Then a matrix is developed which will allow defining of four to six areas (or quadrant if they are four) of uncertainties.
- These areas of uncertainties can then be used to develop four to six possible futures. The driving forces or trends, which were identified earlier, could be seen as characters in the stories that could be developed along the given axes of uncertainties. It is suggested

that it is better to evolve a limited number of scenarios even if it is possible to create a large number of scenarios by combining uncertainties in diverse manner.

- Finally, the scenarios thus developed should be assessed and checked for internal consistency and plausibility. It is suggested that some critical questions could be asked to check the consistency. These would include: "(a) Are the trends compatible within the chosen time frame? (b) Do the scenario combine outcomes of uncertainties that indeed go together? (c) Are the major stakeholders placed in positions that they would not like and can change?

2.2.3 Critiques, Limitations, Concerns

One of the main concerns about the tool of scenario planning is its subjective and heuristic nature. The quality of the product, i.e., the scenario is highly dependent on the process adopted, which in turn is highly subjective and skill-based. This raises questions about the plausibility of the envisioned futures (Wikipedia 2013)

The following are the main weaknesses in the tool of scenario planning (Mats Lindgren and Hans Bandhold 2003).

- Despite the rigorous effort to follow the methodology, the "uncertainty in conclusions" remains, which affects the credibility and acceptance of the conclusions.
- Often the findings of the exercise of Scenario Planning are "counterintuitive" and complex as compared with the simplicity expected by managers or policymakers
- There is tendency to look for firm and quantitative answers, while the tool of scenario planning involves "soft methods" and produce "soft answers", which is often not considered reliable
- Finally, the exercise of scenario planning is seen as "time consuming"

2.2.4 Scenario Planning and Systems Dynamics

Scenario planning may include some aspects of system thinking, specifically the recognition that many factors may combine in complex ways to create sometime surprising futures (due to non-linear feedback loops). The method also allows the inclusion of factors that are difficult to formalize, such as novel insights about the future, deep shifts in values, unprecedented regulations or inventions. Systems thinking used in conjunction with scenario planning leads to plausible scenario story lines because the causal relationship between factors can be demonstrated. In these cases when scenario planning is integrated with a systems thinking approach to scenario development, it is sometimes referred to as structural dynamics (Wikipedia 2013).

2.3 Understanding and Analyzing Indicator Systems

2.3.1 Conceptual Frameworks and Definitions

The literature provides different definitions and underlying conceptual frameworks of indicator systems. In one scheme, the authors present a hierarchy of four levels of concepts to form the system of criteria and indicators. It includes: Principles, Criteria, Indicators, and Verifiers. The concepts successively gain more and more specificity and amplify the scope of the system. At the same time, the hierarchy can be seen as a ladder for increasing aggregation of understanding while going from verifiers to Principles. (CIFOR 1999) In this scheme, the four concepts are defined as follows (CIFOR 1999)(Hart 2008)**:**

(a) Principles: "a fundamental truth or law as the basis of reasoning or action."

(b) Criterion**:** "a principle or standard that a thing is judged by.

(c) Indicator: "an indicator is any variable or component used to infer the status of a particular criterion".

(d) Verifier: "Data or information that enhances the specificity or the ease of assessment of an indicator".

2.3.2 Utility of Indicators and Limitations on Utility

Because the 'Criteria and Indicator Systems' or 'Measurement and Indicator Systems' are tools, it was thought to be prudent to start with the perceptions or expectations about the utility of the tool. The literature discusses the following end-uses for the Indicator Systems. (Crossroads Resource Center 1999; CIFOR 1999; Hart 2008)

1. Raise awareness, engage and build consensus among stakeholders
2. Evaluate Performance of Program or Actions
3. Determine or elaborate of the Status of Situation
4. Present Evidence for Advocating a Cause
5. Report to Different Audiences and to Different Ends

Utility or Importance of Indicators could be summed up as: "What gets measured, gets managed and what is not measured is often ignored" (Hart 2008)

However, it is also pointed out that there are limitations on the utility of indicators as a tool. It is explained: "Indicators offer a snapshot or a glimpse of a larger situation, but don't offer absolute understanding"and, "Indicators can help measure change over time, but don't measure end objectives" (Crossroads Resource Center 1999).

2.3.4 Indicators: Classification, Identification, and Development Process

Different authors have employed different logics for the classification of indicators. One scheme suggests three levels of Indicators: (a) System level, (b) Program / Organizational level, (c) Activity / Action level (Hart 2008).A few other classification schemes include simple differentiation of indicators asqualitative or quantitative or a classification on the basis of targeted audience of the indicators (Crossroads Resource Center 1999).

Another category suggested is the concept of "nested" indicators, which are said to be addressing “issues requiring measurement at different scales”. In the set of nested indicators, “each indicator is appropriate to the scale of the questions being asked” (Crossroads Resource Center 1999).

The process of developing or identifying indicators is important for the present enquiry as it is seen as preparation for a larger project involving use of this tool. Again, different authors describe different processes for developing, identifying, or selecting indicators. As some authors suggest that the starting point of the exercise of developing indicator is to collect all relevant sets of indicators available, sometime the process is referred to as selection or identification of indicators (CIFOR 1999).

Coming to the actual process, the first step seems to be defining the purpose of the assessment system. While defining this purpose, we tend to use many terms and concepts.The second step seems to be ensuring that all these terms and concepts are clearly defined, explained, and understood.The process of defining and clarifying these terms will help us identify the principles and criteria on which the indicator system is to be built. (CIFOR 1999) Once we have the principles and criteria, the next step is to develop indicators. It is suggested that while developing indicators, three critical questions need to be asked: “How many do you need? How do you organize them?How do you make sure they are used?”(Hart 2008).

Hart suggests use of a framework that shows connections among the issues of concern for evolving indicators. According to her, such a framework is useful in four ways: (a) it helps organize the issues, (b) it helps ensure sufficient coverage of issues, it helps show connections and, (d) it provides reporting structure (Hart 2008).

Authors seem to be agreeing with each other on two major aspects:

1. First, indicator development is seen as a participatory process by involving all the stakeholders including community members, decision-makers, and data managers (Crossroads Resource Center 1999; Hart 2008; Long and Hutching 2003)
2. Second, the process is seen as an iterative process, through which the indicator system is to be gradually evolved through higher levels of sophistication by putting it for field testing (CIFOR 1999; Crossroads Resource Center 1999; Long and Hutching 2003)

Maureen Hart suggests keeping sight of: (a) the purpose of the indicators, (b) the audience and what they will use the indicators for, (c) the geographic, ecological, as well as substantive boundaries. She also emphasizes that the"process by which indicators are developed is as important as the final product"(Hart 2008). She explains further that "collaboration is the key" because indicators must measure something that is: (a) publicly valued, (b) be understood by those who will use them, (c) be seen as credible and meaningful, (d) be linked (conceptually and practically) to policies andactions (Hart 2008).

2.3.5 Desired Attributes for Selection of Indicators

The following nine attributes are presented to test the indicators (CIFOR 1999):

1. Relevant to the issues that define the area of concern
2. Closely and unambiguously related logically to the assessment goal
3. Precisely defined
4. Diagnostically specific
5. Easy to detect, record and interpret
6. Reliable
7. Adequately comprehensive to cover all the possibilities under the given conditions
8. Providing a summary or integrative measure over space and /or time

9. Appealing to users

2.4 System Dynamics Modelling

2.4.1 Systems Thinking

The foundation of system dynamics modeling rests in systems thinking, systems approach, or systems' world-view. As per Kirkwood, systems thinking "requires that we move away from conventional way of looking at things in terms of event based observation and move towards looking at the broader picture, as a system made up of interacting parts"(Kirkwood 1998). It involves thinking in terms of "patterns of behavior" and looking for "structure of the system" (Kirkwood 1998). Coming to its utility, systems thinking is seen as equipping decision-makers for "better understanding of the difficult problems", as the root cause of most problems are found to be lying in the underlying structure of the system (Kirkwood 1998).

2.4.2 Patterns of Behaviors

The key to unravelling the underlying structure of the system lies in identification of the 'patterns of behavior.' This involves "observing how one or more of the variables of interest changes over time, i.e., what kind of pattern of behavior do these variables display over time" (Kirkwood 1998). It has been observed that "similar patterns of behaviors show up in variety of different situations" (Kirkwood 1998). This allows us to identify the related structure of the system present in these situations, wherein the root-causes of the problems could be found. This lends immense power to the system approach as a method for solving otherwise intractable problems.

2.4.3 Feedback Loops and Their Behavior

Feedback loop can be defined as "a closed sequence of causes and effects, that is, a closed path of action and information" (Kirkwood 1998). To understand the above mentioned patterns of behavior, it is useful and important to understand the feedback loops, as the cause of the behavior is often found in the feedback structure (Kirkwood 1998).

2.4.4 Causal Loop Diagrams

Feedback loops and structures are only a starting point for understanding and analyzing what is causing a particular pattern of behavior(Kirkwood 1998). According to Sterman, Causal Loop diagrams are simply "maps showing the causal links among variables arrows from a cause to an effect" which depict the feedback structure of the system (Sterman 2000). Causal Link is essentially the cause and effect relationship between two variables (Sterman 2000). There are two kinds of causal links: Positive or Negative. If increase or decrease in the cause of a cause and effect relationship leads to corresponding increase or decrease in the effect, then it is considered a positive causal link ((Sterman 2000). Similarly, if an increase or decrease in the cause of a cause and effect relationship leads to corresponding change in the opposite regard, that is decrease or increase in the effect, then it is considered a negative causal link (Sterman 2000).

Feedback loops can also be classified based on behavior. Positive or Reinforcing feedback loop is defined as "A feedback loop is called positive, indicates by a + sign in parentheses, if it contains and even number of negative causal links"(Kirkwood 1998). It reinforces change and leads to rapid growth with ever-increasing rate of growth(Kirkwood 1998). It is also referred to as exponential growth. In early stages, the problem can come across as minor, but as time passes the growth speeds up and the problem increases rapidly. Such positive feedback loops are called vicious cycles. Sometimes if the change is helpful, then the positive feedback loops are called virtuous cycles (Kirkwood 1998).

Negative or Balancing Feedback loop is defined as "A feedback loop is called negative, indicates by a - sign in parentheses, if it contains and odd number of negative causal links" (Kirkwood 1998). These loops seek a goal and display what is referred to as 'Goal Seeking

Behavior'. It pushes the current value of the variable of interest towards a goal. They can provide stability and also resist much needed change (Kirkwood 1998).

There can be delays in the cause and effect relationship, where the influence of the cause is observed in the change in effect after passing of some time (Sterman 2000). Negative Feedback loops with delay are "balancing loops having causal relationships that show substantial effect after a certain time passes"(Kirkwood 1998). In such a case, the value of the variable of effect might overshoot the goal value while trying to achieve it and continues trying to achieve the goal value leading oscillating behavior(Kirkwood 1998).

The combination of positive and negative feedback loops are frequently observed in the real world. Most growth processes have limits on their growth and at some given point the positive feedback loop in the combination will be dominated by the negative feedback loop(Kirkwood 1998). This results in the combination of displaying first an exponential growth and then goal- seeking behavior. This is called the S-shaped behavior(Kirkwood 1998).

2.4.5 Stock and Flow diagrams

Stock and Flow diagrams are diagrams that 'emphasize their underlying physical structure and "track accumulations of material, money, and information as they move through a system" (Sterman 2000). Stocks and flows are considered as the important building blocks of the system (Ford 1999). Stocks are key variables that represent "where accumulation or storage in the system takes place"(Ford 1999). Flows are connections between stocks that directly influence them and are "actions to change the system to a new state"(Ford 1999).

2.4.6 System Dynamics Modeling

Modeling is an iterative process. In his book Business Dynamics, John Sterman describes the stages of the modeling process as follows(Sterman 2000):

1. **Problem and Boundary Definition**: Problem and Boundary Definition is a very important stage as it decides the structure and working of the model. This stage tries to answer different questions like: What is the purpose of the model? What is the problem observed? What key variables should we consider? How far ahead in the future and how far back in the past should we think? What are the reference modes i.e. the historical trends observed in the key variables? How can these trends change in the future?

2. **Dynamic Hypothesis**: This stage analyses different theories about the problematic behavior observed. So it is important to formulate a dynamic hypothesis, a hypothesis about the changing behavior of the system and how it comes about because of the feedbacks in the system. It takes an 'endogenous focus'. Mapping out these theories to form a causal structure (a map of cause and effect linkages) is also a part of this stage. This can be done in a Causal-Loop Diagram or a Stock and Flow Diagram. In many models Causal Loop Diagrams are the first step of mapping as it helps the modeler to get a clear understanding of the system. This is followed by a Stock and Flow diagram of the same problem, based on the Causal Loop Diagram.

3. **Formulation of Simulation Model**: This stage involves building the model by the help of a software like Stela or Vensim. This involves mapping out the causal linkages, variables and stocks and flows then connecting them to each other using equations, and finally adding the related data. This helps in specifying the structure, decision rules, behavioral relationships and initial conditions. Running the model gives the modeler trends and values of different variables.

4. **Testing:** This stage helps us determine if the model works properly or there have been any mistakes in understanding and building the model. Tests for robustness and sensitivity of the model tell us if it is showing realistic behavior of the system and

variables.

5. **Policy Design and Evaluation**: This stage involves finding scenarios and possibilities, designing strategies and policies based on these scenarios, how these policies might change the behavior of different variables, how robust are these policies under these different scenarios and extreme changes

2. 5 Connecting the Three Research Tools

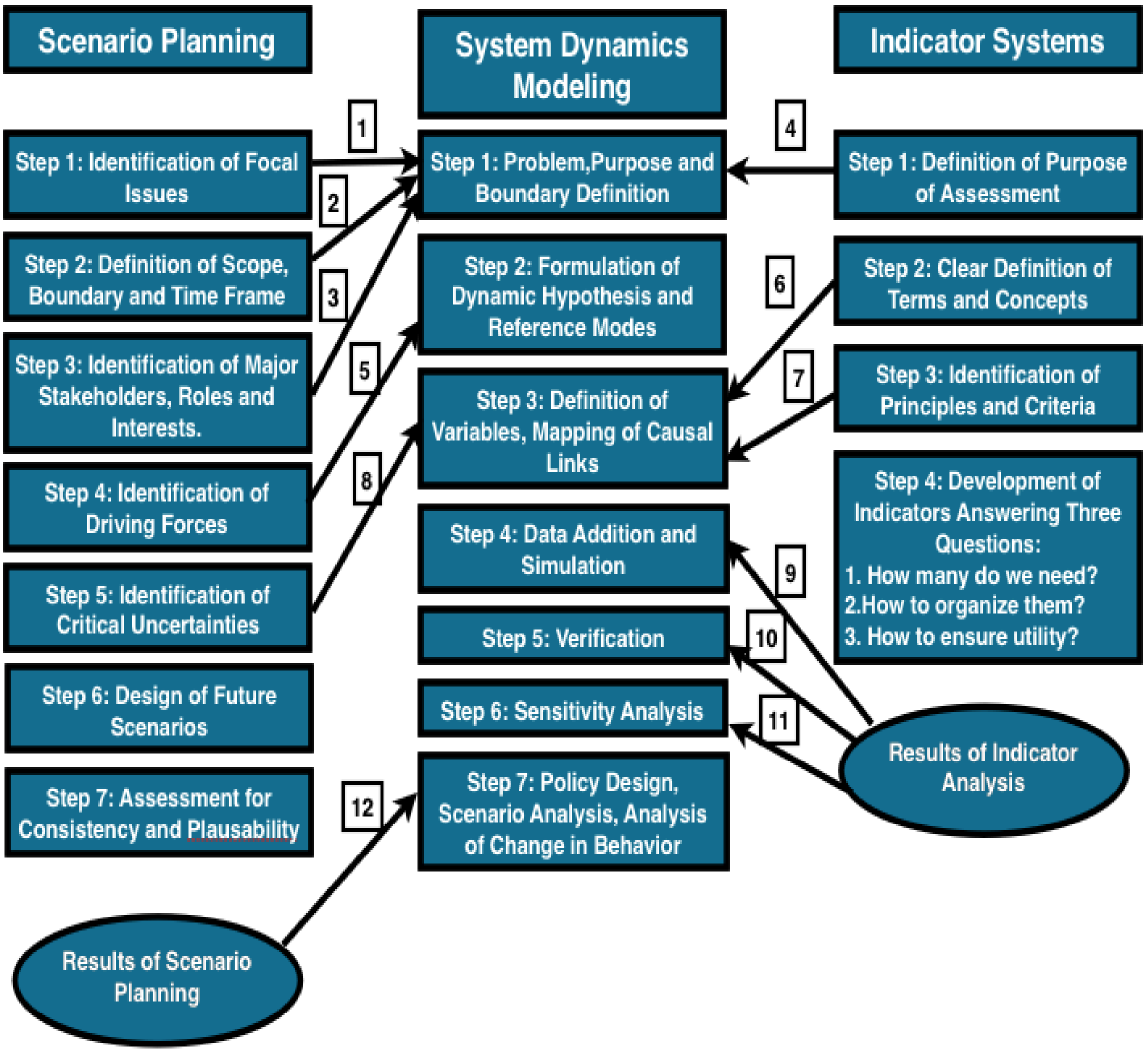

Figure 2.3 Connecting the Three Tools

In the previous sections, the three tools and their procedural steps have been discussed. Many common grounds and principles could be observed in the various steps of these different tools. In this section, the researcher presents some ideas about how to make effective use of the knowledge base—including conceptual frameworks, procedural steps, data, and findings—created by the previous research conducted using the tools of Scenario Planning and Indicators Analysis in order to build a useful system dynamics model.

In Figure (2.3) above, the main procedural steps in application of the three tools are presented in a summarized form. The figure also indicates interconnections—using arrows—among the procedural steps of the three tools. The arrows depict that a certain step in the two tools and the data obtained from it can contribute to a certain step in the SD modeling process.

The following is the explanation for the connections indicated by the arrows with respective numbers. The elaborate the ways in which inputs can be drawn for the particular steps in building the SD model from the knowledge base created by research using SP and IS tools.

1. Identification of focal issue in the scenario analysis procedure can help define the core problem of the required SD model. Since the problem defines the model, its boundaries, its purpose and it's working, this is a crucial contribution to SD Modeling from the other tool.
2. The step of Defining Scope, Boundary and Time frame, which is required for the model building process is already done in the Scenario Analysis step and can be imported to the model building process
3. Identification and involvement of stakeholders is a crucial factor in defining the purpose, problem, scope and boundaries as it gives the model a more holistic start. Since this is already done in the Scenarios analysis it can be used to help formulate the model problem and boundaries

4. The step of defining Purpose of Assessment during development of Indicators can also be used to define the core problem of the model as it specifies which area is problematic and needs to be assessed.

5. The step of identification of Driving forces in the tool of Scenario Analysis will help identify the crucial variables and trends and build the dynamic hypothesis about what trend in which variable is causing the problematic behavior of another variable

6. In a systems dynamics model, the step of defining the variables is a very crucial aspect. In the Indicator analysis, the terms and concepts have been clearly defined, with inputs from and understanding of the different stakeholders. Using these pre-defined terms and concepts, removes ambiguity.

7. Similarly, clear ideas about cause-and-effect relationships between different variables are crucial in a model as well. Identifying Principles in the Indicator Analysis helps make these relationships clearer in terms of ' how things work'

8. Identification of critical uncertainties step from Scenario Analysis is useful to define and map out cause and effect relationships as it points out gaps and missing connections.

9. Indicator Analysis gives important data as results of its application, which can be used to simulate the model.

10. Similarly, results in the form of data and trends obtained from the indicator analysis can also be used to tally against the results of the model to test if the model works properly.

11. Results of the Indicator analysis can also point out to which are the critical variables to observe during the evaluation

12. Results of the scenario analysis give us a set of scenarios to observe and evaluate in the ready model. It also suggests which policy designs and interventions to try out.

2.6 Participatory System Dynamics Modelling

2.6.1 Different Methods for System Dynamics Modeling

For engagement in system dynamics modeling, there are two major pathways: modeling projects versus group modeling projects (Berard 2010). As Berard (2010) explains, the first type is where modelers themselves design models by gaining the expertise and required data from various sources, and often inputs from experts on the modeled system. For the second type of project, experts on the system are not considered as only a source of information, but are invited to build and elaborate models with the help of a modeler. Further, there are many other ways to conduct the group model building type of projects, which involve including different stakeholders, ranging from experts to general public. As the literature on the application of system dynamics on SES indicated, as this research is dealing with socio-ecological systems, it is necessary that this researcher goes beyond the 'modeler only' approach and involve other stakeholders (Winz and Brierley n.d.; Stave 2010; Yadama, Hovmand, and Chalise n.d.)

> Sustainable environmental management requires a decision support approach that accounts for dynamic connections between social and ecological systems, integrates stakeholder deliberation with scientific analysis, incorporates diverse stakeholder knowledge, and fosters relationships among stakeholders that can accommodate changing information and changing social and environmental conditions. Participatory system dynamics modeling provides such a framework. . . . Appreciation of the scientific uncertainties, multiple and often conflicting stakeholder goals and values, and interconnected environmental and social dynamics that characterize environmental issues has led to calls for management frameworks that facilitate deliberation among stakeholders as well as scientific analysis in support of decision-making (Stave 2010).

2.6.2 Group Model Building (GMB)

GMB is the model of PSD that has dominant presence in the system dynamics research literature as it one of the most used methods of PSD, gathering immense understanding and experiences and developing a wide scale of insights in PSD (Winz and Brierley n.d.). The GMB projects carry some main characteristics. In these projects people work in groups and construct models together to tackle 'messy' problems (Winz and Brierley n.d.).Further, the time frame of GMB "can range from one day to several years and group sizes can vary between a handful to up to 100" (Winz and Brierley n.d.). The GMB method is used either for decision-making or for consensus building.

The other method, Community Driven Systems Dynamics (CDSD) is developed and practiced by Prof. Peter Hovmand and Prof Yedama of Washington. They call it "our 'community driven' philosophy"(Yadama, Hovmand, and Chalise n.d.). As it draws heavily from GMB, it can be seen as an application of GMB that has highly enhanced level of participation of stakeholders, more specifically the community. It is said to be more relevant for research in socio-ecological systems. They state:

> A significant concern in developing dynamic models of social-ecological systems is the source of data and the way it is derived which assures a high level of confidence in the dynamic behaviour. It is our contention that experts – academic, government, or nongovernment – may know some of the processes that link social and ecological systems but are poor substitutes for actual households and communities that make daily decisions which over time shape livelihoods and influence local ecologies (Yadama, Hovmand, and Chalise n.d.).

2.6.3 Advantages of PSD

Many authors have listed different advantages of the Participatory System Dynamics. These include: achieving higher quality of decisions, building capacities, promoting social learning, helping resolve conflict and build consensus, and creating networking opportunities (Winz and Brierley n.d.).

Participatory System Dynamics (PSD) is said to have fifty-year long history, but there is exponential growth in PSD based research in the last two decades. During this period, the nature of involvement of stakeholders has underwent significant change, from that of being "information providers" to "more intense and . . . characterized by continuous information feedback processes" (Winz and Brierley n.d.)

Further, it is also said that the SD Model provides "a neutral platform for the evaluation of contentious policies . . . while helping avoid interpersonal conflicts", in other words, "Having the model "tell" the group the likely consequences of a particular decision can be more powerful than having a person tell the group" (Stave 2010).

In the case of GMB, according to Celine Berard (2010) experience is said to have "highlighted the importance of involving many participants in the modeling process, with the aim of increasing the relevance and usefulness of the model". More specifically, she states, "at the individual level, the approach [GMB] improves the mental models of participants. At the collective level, it allows the alignment of the mental models, the achievement of a consensus with respect to decisions, and the involvement of the group with respect to these decisions" (Berard 2010). It is also suggested that "[f]acilitated group projects [in GMB] are particularly useful when stakes are high and stakeholder objectives conflicting" (Winz and Brierley n.d.).

2.6.4 Challenges and Limitations of Participation in SD

Alongside its advantages, the challenges and limitations of the participatory approach for SD modeling have been articulated and underscored by many authors. To being with, at more general level, the wider participation is said to involve significant costs of three types: Monetary, Non-monetary, and potential hidden costs (Winz and Brierley n.d.).

In the case of participatory practices in SD modeling, it is pointed out that "laypersons lack an understanding of concepts such as uncertainty and the scientific process, have insufficient knowledge" (Winz and Brierley n.d.). Further, it is stated that mental models of people are generally indistinct, messy, and incomplete which contribute to ineffective policy and programs (Yadama, Hovmand, and Chalise n.d.). More specifically, in the case of issues pertaining to environmental management, it is indicated that "in order to address environmental problems systemically, all actors that are part of the system need to be a part of the decision making process" (Winz and Brierley n.d.).

Coming to GMB interventions, it is pointed out: "the full-scale group workshops [expected under GMB] may neither always be neither feasible nor desirable. Group processes are particularly time-expensive and require extensive scheduling — and often rescheduling — of meetings for all involved" (Winz and Brierley n.d.)PSD in general and GMB in particular, is said to require a rapport between client institution/stakeholders and the modeling team. This may lead to multiple interviews before the actual intervention can begin. (Winz and Brierley n.d.)The PSD initiatives involving participation of members of community, especially poor communities face peculiar problems:

> It became evident that it is difficult to identify and agree on a dynamic problem between villagers who are deeply embedded in the problem, the nongovernmental organization working to address the problem, and the modelling team. Gaining perspective on a problem is difficult when livelihoods are at stake. Unlike problems that are routinely analysed by experts and modellers, villagers and social change advocates alike are not dispassionate about the dynamic problem. While engaging such actors provides accurate data and portrayal of the problem, it is considerably difficult to define the dynamic problem itself (Yadama, Hovmand, and Chalise n.d.).

2.6.5 Research Techniques, Procedures, and Tools Used in PSD

There is a significant level of variety in techniques as well as procedures used for carrying out various stages of the modeling while using different methods of participatory system dynamics. It is observed that "it is difficult to obtain a global [universally applied] vision of the procedures to follow to carry out such a group project, in order to model a system using system dynamics" (Berard 2010).

Coming to the techniques that are used, the list provided by Celine Berard includes: (a) Delphi method and the nominal group technique, (b) brainstorming tools, (c) semantically rich scenario maps to formal influence diagrams (Berard 2010). Effort has also been made to identify the techniques appropriate for different stages of the SD model-building. Berard (2010) suggested that "the tasks related to the design of a level-rate diagram must be based on individual meetings with participants or on small nominal groups, as well as on structured and systematized group activities, . . . [while] the tasks related to the development of mathematical equations are rarely completed with the entire group". According to her, generally, elicitation of participants' knowledge is said to become "more and more complex during the quantitative modeling process" (Berard 2010). The researchers using the CDSD method, combine "participatory rural appraisal techniques with group model building [techniques]".(Yadama, Hovmand, and Chalise n.d.)

Coming to the procedures used in the PSD exercises, the GMB initiatives are composed of "three broad phases: pre-meeting activities, the actual meetings and post-meeting follow-up activities" (Winz and Brierley n.d.). These actual meetings are also referred to as group modeling workshops, work sessions or conferences. In the actual meetings or sessions it is expected that "the participants [would] develop one or many models during structured sessions with the help of a facilitator" (Berard 2010).

Celine Berard also provides some details of the procedures used in the four studies using Participatory systems Dynamics Modeling(Berard 2010). These include: (a) the duration and frequency: from one-time process involving a 2 to 3 hour workshop, to one of two year processes with monthly meeting of 2 hours, (b) the size of the group varies from 1 to 4 people per computer (c) the groups were "self-directed, sometime "facilitator-led"(d) participant number vary from 5 people to 20, 30 or 100 people, (e) participants include from general public to officials, planner, and stakeholders' representatives, environmental groups (Berard 2010). Coming to the actual 'tools' or 'implements' used during conduct of these exercises, the common tool used by many researchers including those using GMB method are called as scripts, which describe the "meticulously planned activities" (Winz and Brierley n.d.). The scripts essentially contain details of procedures to be followed in the conduct of the participatory sessions using the different techniques. Scripts are used in a big way, during the GMB exercises (Berard 2010). Even the proponents of Community Driven System Dynamics make use of these scripts (Yadama, Hovmand, and Chalise n.d.).

Chapter 3:Developing Methodology for the Thesis Research

This chapter presents three sections related to different aspects of the overall methodology for this research. The first section presents some elements of the research design in continuation of the research design presented in Chapter 1. The second section in this chapter presents the methodological procedure, which was developed for responding to the first research question. The procedure involves building a system dynamics model using inputs drawn from the research using the tools of Scenario Planning and Indicator Systems.

In the third section, first, a methodological procedure is developed for conducting sessions based on the Participatory System Dynamics (PSD) method. This procedure was applied during the actual research work. However, the researcher had to make some changes and revisions in the planned procedure in view of the actual field situation. These changes and revisions are presented in the second sub-section of this third section.

3.1 Evolving Research Tasks for the Research Questions

This section takes the research design to the next logical step. It operationalizes the two research questions presented in the first chapter by breaking down each research question in objectives that need to be fulfilled in order to find answers.

The first research question is about creating a base conceptual model to help the modeler understand better the SES of the Balaton region. It was articulated as follows:

1. What are the inputs from the previous research conducted using the tools of SP and Indicator Systems that can be used to create a conceptual system dynamics model, as a base for understanding the Balaton SES by?

This research question was broken down into the following objectives:

a. To identify problem areas in the SES based on the literature

b. To identify from the literature the recurring themes that might form the subsystems

c. To identify causal linkages connected to these themes

d. To transfer the information into a Causal Loop Diagram (CLD) format

e. To identify inputs to conduct the Participatory System Dynamics (PSD) sessions

The secondresearch question pertains to using inputs from PSD sessions to create a pilot-level model of the Balaton SES that can be used in later stages for various purposes. The research question was articulated as:

2. What inputs from sessions with representatives of stakeholders based on the Participatory System Dynamics methods can we use to build a pilot level, conceptual system dynamics model of the Balaton SES using?

This research question was broken down into the following objectives:

a. To create scripts (i.e., formats) for the PSD sessions

b. To identify new themes emerging from the discussions in the sessions

c. To create causal loop diagrams for each theme (both old and new)

d. To add stock and flow structures wherever necessary

e. To convert themes into layers of the model

f. To add inter-layer feedbacks

g. To identify gaps, implications and future opportunities

3.2 Procedure for Creating System Dynamics Model Using Inputs from Previous Research

This section describes the methodological procedure developed for addressing the first research question and its related tasks. The main expected outcome of the first research question was developing a base level model describing the SES by using the possible inputs from the previous research based on the tools of indicator systems and scenario planning.

Section 2.5 presented the connections between the three research tools that were derived on the basis of the review and analysis of the literature on these three tools. Based on these connections, a procedure was evolved in the second chapter for developing the simulated system dynamics model based on the inputs from the previous research.

However, considering the limitations on time and resources available for this research, the system dynamics model was developed only in the form of a conceptual model primarily containing the Causal Loop Diagram (CLD). As a result, only some connections identified in Section 2.5 were used for the development of the methodological procedure used in this research. To be more specific, inputs from the indicators and scenario planning tools were used only up to Step 3 of the model building process as described in Figure 2.3. The steps covered in this section are shown in Figure 3.1.

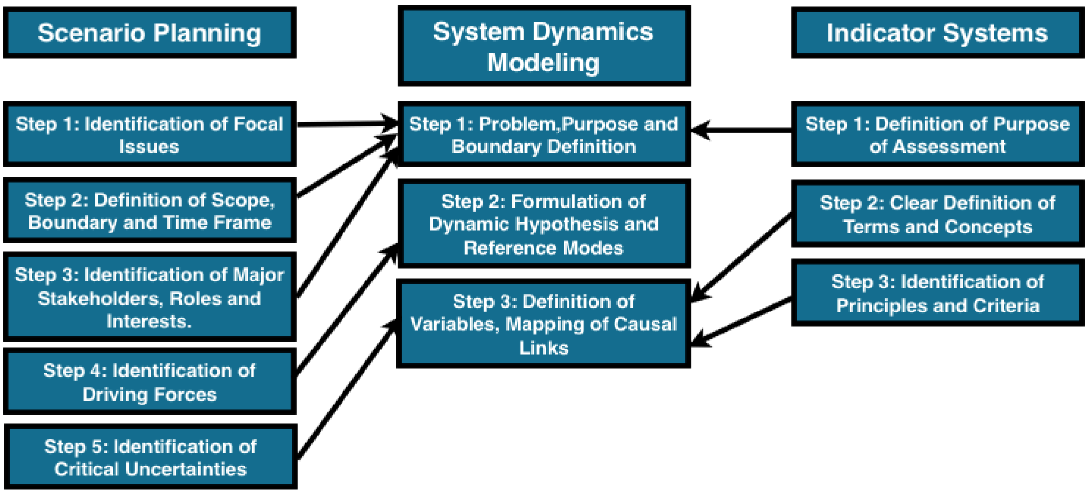

Figure 3.1: Steps for Building Base-Level System Dynamics Model

The review of the findings of previous research using the two research tools clearly identified the main problems areas and recurring themes. Once the problems were identified and the recurring themes listed, the stakeholders were identified based on the existing research. People already involved in the previous research were requested to participate in the PSD sessions. The driving forces identified in the research using the tool of Scenario Analysis helped the researcher identify the crucial variables and trends and build the first order dynamic hypothesis. It helped the researcher build an understanding of the trend of the changes in the variable that is causing the problematic behavior of another variable. In the previous research, the terms and concepts have been clearly defined, with inputs from the understanding of the different stakeholders. Thus, it led to a better understanding of the system by the researcher and elimination of ambiguity. The specific inputs were then converted into causal links wherever possible. The causal loop diagrams were built by linking the relevant causal links.

3.3. Methodological Procedure for Participatory System Dynamics Sessions

Various experts and stakeholders were consulted and engaged in the exercises using the methods and tools of the Participatory Systems Dynamics (PSD) Modeling. Different experts and stakeholders were involved in different stages of the process. The process of engagement with the stakeholders started with eight people who were closely connected with the previous research in the region, using indicator systems and scenario planning. Inputs were obtained from, in all, 12 respondents on different aspects and in different stages of the process. This is an on-going process and more inputs from new respondents are expected in the course of time.

3.3.1 Planned Methodology for the Participatory System Dynamics Exercises

Ideally, the process would benefit from three sessions with each participant of around two hours each. The first two sessions would be one-on-one sessions, and the third session, if possible, would be with all the participants together, where there can be a discussion about the utility of the model. There could also be a fourth session with all the respondent s and stakeholders to assess the utility of the model and obtain comments for corrections and the finalization of the model. Keeping this in mind, the following steps were planned before starting the sessions:

First Level PSD Sessions: Individual Interaction for Model Building

In the first-level sessions, the following objectives are to be fulfilled:

a. Identification of the central problem(s) and system boundaries

b. Understanding the perceptions about the system of the respondent, by mapping out their mental maps of the system in the form of causal links and the Causal Loop Diagram

c. Identifying the stocks from the narration of the system linkages by the respondent

Second Level PSD Sessions: Individual Interactions for Verification and Quantification

In the second-level sessions, the following objectives are to be fulfilled:

a. Presenting the combined stock and flow diagram based on discussion in the first sessions with all respondents

b. Revising the model through interactions with respondent by incorporating the changes, corrections or additions in the model

c. Identifying and understanding working of unquantifiable variables

d. Building individual causal loop diagrams around these variables

e. Trying to pinpoint quantifiable proxy variables for the unquantifiable variables that depict closest behavior of the unquantifiable variable and drive system behaviors in a similar manner as the unquantifiable variables

f. Checking data availability for the proxy variables

g. If not, getting the respondents' approximations on data and equations for the time being

Third Level PSD Sessions: Joint Exercises for Assessment of Utility of the Model

In the third-level sessions, the following objectives are to be fulfilled:

a. Presenting the quantified model and simulation of it in the presence of all the respondents

b. Discussion by the respondents on the simulated model and simulation of various scenarios and assessment of the model to check weather is shows observed behavior

c. Making necessary changes in the model based on the inputs from the respondents

d. Making necessary changes to the interface of the model and discussion regarding the ease of operation and use of the model for various stakeholders

e. Comments from respondents regarding the utility of the model, sharing of insights in the process of model building and future scope and changes

3.3.2 Revisions in the Planned PSD Procedure

During the actual PSD sessions, the researcher had to make some changes and revisions in the planned procedure described in the earlier sub-section. These are briefly described in the following paragraphs.

The PSD sessions were conducted in person or via Skype. During the in-person sessions, the researcher used to draw causal linkages and causal loop diagrams on paper, during the flow of the conversation with the respondents. The Skype sessions were conducted in a similar manner, substituting the use of the computer software Vensim for paper and using the screen-share option in Skype.

While conducting the individual sessions, the researcher did not direct the conversation towards the identification of stocks and flows, as it could have hampered the flow of the conversation. Regarding the conversation of boundaries, it was observed that the boundaries of the watershed do not apply to some layers and for the themes emerging, so it was also included in the points to be discussed later in group sessions.

Due to limitations of time, busy schedules of the respondents, and the happy coincidence of a few of the respondents were able to join in for a group session on the same day. Hence, most of the second-level PSD sessions were clubbed into a third-level group PSD session. The discussion in this third-level group session, in which the following topics were covered: (a) comments on the current pilot level model, (b) verification of the existing causal structure, gaps, variables that needed to be defined, (c) links that needed to be clarified, (d) future steps, and (e) the utility of the model. Some of the respondents, who could not join the group session, were engaged in the individual manner, in the second-level PSD sessions that tried to cover the same points mentioned above. However, some new respondents joined in for the group session and provided inputs to the model.

Chapter 4:Lake Balaton Watershed: Learning from Literature and Previous Research

In its first section, this chapter presents background discussion on the situation in the Lake Balaton region based on the review and analysis of literature. In its second section, it responds to the first research question, about building a system dynamics model of the socio-ecological system in the Lake Balaton region, using inputs from previous research based on the research tools of scenario planning and indicator systems. In doing this, it makes use of the methodology developed for this purpose in the previous chapter. This model will be used in Chapter 5 as a basis to build the system dynamics model of the Balaton SES, using inputs from sessions with representatives of stakeholders using Participatory System Dynamics methods.

4.1. Balaton Watershed: Diverse Concerns and Measures

4.1.1 Brief History of the Lake and the Region

Lake Balaton is the second largest lake in Europe and is located in the western part of Hungary. It is considered as one of the treasured natural assets of Hungary and of the Central European region. The picturesque lake is an important tourist attraction in Hungary and has tremendous economic importance for the country as well as the region.It is also a region with not just symbolic and cultural importance to Hungarians but also the many international visitors to the region (Pinter et al. 2008).

The lake which was used for fishing and agricultural activities in the earlier era, started witnessing economic activities in the form of shipping after the steam navigation was introduced in the 19th century. The tourism activities are traced to 1920, when the Treaty of Trianon was signed (Horvath 2011). Through the large part of the 20th century and after, tourism has been the main source of income for small businesses and municipalities in the towns around Lake Balaton (Bizikova and Pinter 2009). Hence, tourism is called as the 'flagship of economy' in the Balaton region (Bizikova and Pinter 2009).

As a result, a separate area around the lake, dependent on the tourism industry was carved out and called as the Lake Balaton Recreational Area (LBRA). It is reported as composed of 179 municipalities, 255,000 permanent population, 171, 500 houses (Varga n.d.). This region represents the highest share of the tourist industry in the country's economy and also has the highest proportion of Hungary's total number of hotels, which are concentrated around the lake. In 2005, there were about 8,900 tourism enterprises operating in the region (Bizikova and Pinter 2009).

4.1.2 Water Level in the Lake Balaton: A Major Concern

Lake Balaton is a naturally shallow lake, with an average depth of 3.3 m. The area of the lake is 594 sq. kms., with the catchment area of 5775 sq. kms. (Varga n.d.). Figure 4.1 presents a map of the catchment area of the Balaton watershed of Lake.

Being a shallow lake, the water level in the lake is a matter of great concern, considering it is of economic and cultural importance for the region. The "moderately wet continental" climate is seen as having a significant influence on the water level in the lake (Bizikova and Pinter 2009). The water level in the lake is considered as "highly sensitive to changes in weather patterns, ecological impacts and management decisions" (Bizikova and Pinter 2009). In the long history of the region, climatic variations have resulted in significant variations in the water level of the lake. Figure 4.2 presents a broad-brush picture of the water levels in the Lake Balaton from 800 B.C. (Novaky B. 2007).

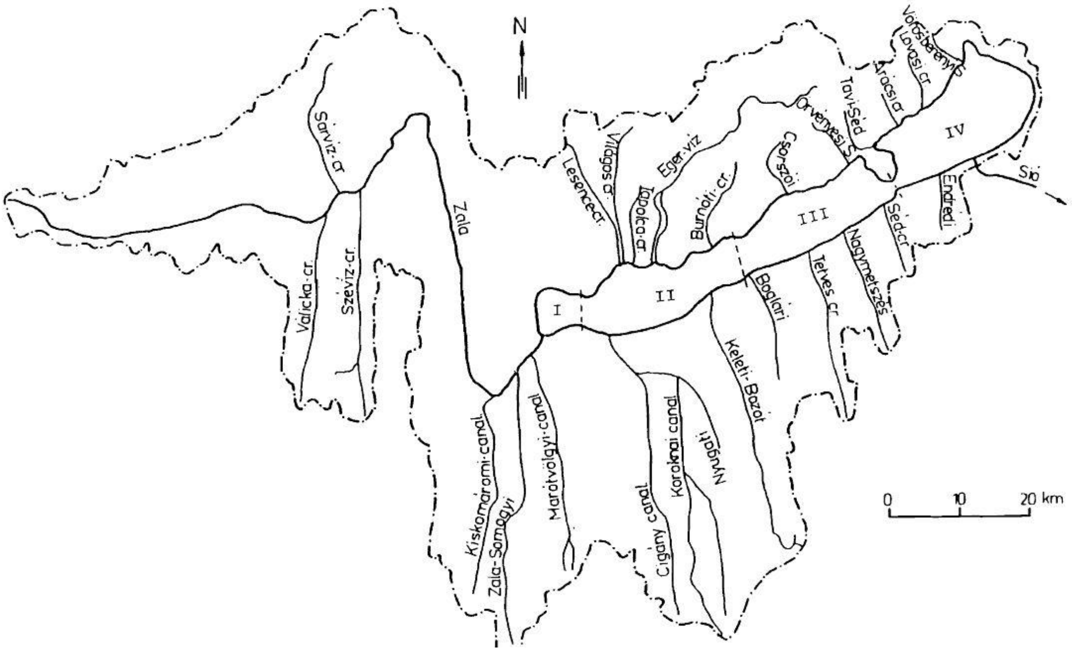

Figure 4.1: Catchment area and river system of the Lake Balaton

[Source: (Straten and Somyodi 1980)]

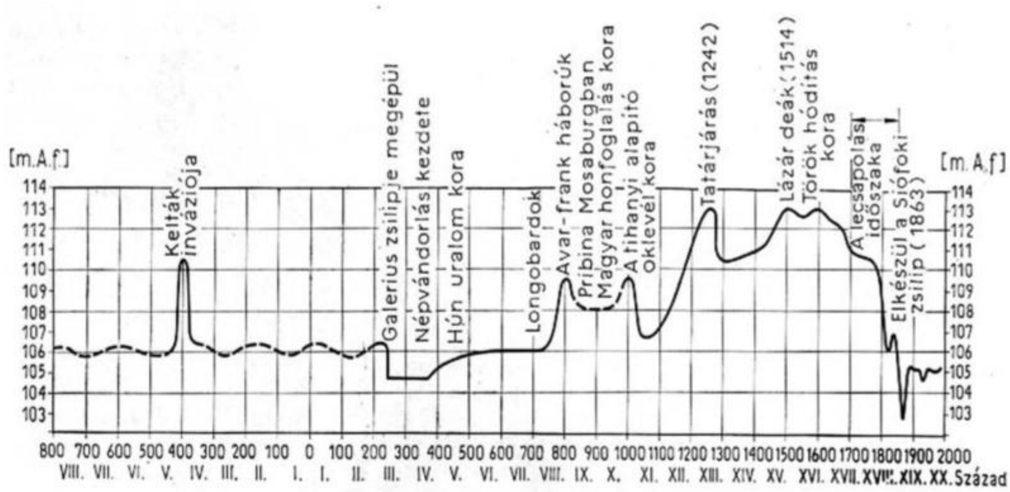

Figure 4.2: Fluctuation of the Water Level of the Lake Balaton from 800 B.C.
[Source: (Novaky B. 2007)]

Apart from climatic and natural factors, human interventions have also been a major factor in affecting the water level in the lake (Horvath 2011). The history of human intervention has been traced to the efforts of Roman to build a drainage system to protect their military roads from floods at the location of the current town of Siofok(Horvath 2011). In 1863, a wooden sluice gate was built on the periphery of the lake in the estuary of the Sio-canal in order to "regulate the fluctuations in the water level in the lake and thus to avoid extreme floods and droughts situations" (Horvath 2011). This is said to have hindered shipping activities. At present, the water level is still controlled by the sluice gate on the weir at the head of the Sio canal. The water level in the lake is currently maintained within the range of only 40 cms., with 3.13 meters of the average depth is considered as the minimum water level required in the lake (Horvath 2011).

The Sió sluice gate, as the only, critical, and indispensible tool to maintain the water level, also determines and helps manage, in the process, the water balance of the Lake Balaton region in the face of variations in the weather patterns and precipitation levels. In the last few decades, the region has witnessed "both very humid and very arid seasons, when the water level had to be severely controlled" (Horvath 2011). It is reported that, in the year 1965, 1.08 billion m3 of water had to be sluiced through the Sió canal to avoid floods. As against this, during the extremely arid years in the beginning of the 21st century, in order to maintain water in the lake, the sluice gate was kept closed for more than five years (Horvath 2011).

4.1.3 Current Issues around Sustainability in Balaton Region

The area around the Lake Balaton, like all natural ecosystems, is continually evolving due to the dual effects of natural change and anthropogenic change (Pinter et al. 2008). Due to intense interactions between human societies and the surrounding ecological systems, the watershed areas and more specifically lake areas are seen as one of the most fragile areas (Horvath 2011). Human interventions play an important role in the ecological dynamics of Lake Balaton and the social aspects connected to the lake (Pinter et al. 2008). In contrast to the past, both, the delicate ecology of the lake and economic activities that are critically dependent on the lake have become highly susceptible to any climatic variations, resulting in seriously adverse impacts (Pinter et al. 2008).

In the years 2000 to 2003, precipitation levels in the region dropped to very low levels "resulting in lower than normal water levels" in the lake (Bizikova and Pinter 2009). Further, higher temperatures during these years also led to increased evaporation, and the decrease in water levels (Bizikova and Pinter 2009). Figure 4.3 presents a vivid comparative picture of the low water levels during the period. This fall in the water level in the period between the years 2000 and 2004 was considered a dramatic issue in the ecological history of the Lake Balaton (Pinter et al. 2008).

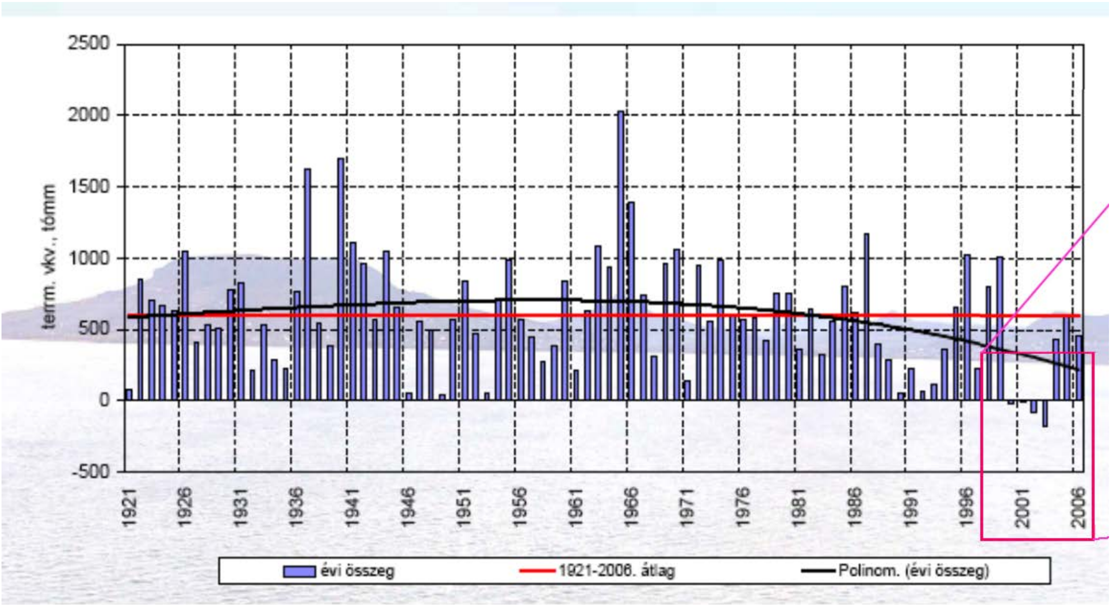

Figure 4.3: Drastic Fall in Water Levels in the Years 2000 to 2003

[Source: (Varga n.d.)]

This incident at the beginning of the 21st century is not seen by many as an isolated incidence (Horvath 2011). Following the patterns of rapid climatic changes at the global level, the climate in the Lake Balaton region is also expected to change and resemble a Mediterranean-like climate, with milder, rainy winters, and hotter, drier summers. However, an increase in winter precipitation is not likely to balance the summer aridity; therefore, the overall precipitation is expected to decrease affecting the natural evolution of our water bodies (Horvath 2011). However, this dramatic incidence drew the attention of decision makers and stakeholders to the fact that one of the most important ecosystems in Central Europe is endangered (Pinter et al. 2008). The event when juxtaposed with water quality problems prompted questions about "the vulnerability of the area with respect to climate change. . . This is especially pertinent in scenarios where the effects of climate change are aggravated by other pressures such as the development of natural landscapes" (Lake Balaton Development Council n.d.).

As a result, apprehensions were also expressed about the ability of the system of governance of the Lake Balaton Region to effectively cope with climate change (Pinter et al. 2008).

4.1.4 Previous Sustainability Measures and Research

The awareness of the ecological problems and the need to protect shoreline settlements and their economies have led to many measures, including technical and administrative measures. For example, in order to reduce eutrophic inflows, a sewage treatment system was constructed around the lake. Construction moratoriums were introduced in order to protect the physical and ecological characteristics of the shoreline (Horvath 2011).

Coming to the administrative measure, the 'Lake Balaton Recreational Area' is considered officially as a separate development region. Further, the legal instrument, which is called as the Balaton Law, was introduced in the year 2000. It is considered as a landmark in efforts to ensure the sustainability of the Region, as "it provides a comprehensive development plan for the 'Lake Balaton Recreational Area', with regard to environmental aspects. . . . encouraging socially responsible and environmentally sustainable political decisions"(Horvath 2011).

An elaborate institutional structure has been created in the form of institutions such as the Lake Balaton Development Council and the Lake Balaton Development Coordination Agency, which is a development arm of the Council (Lake Balaton Development Council n.d.). One of the most important tasks given to the Agency is to develop regional cooperation in the Lake Balaton Recreation Area in order to ensure "sustainable tourism development, environmental protection, traffic infrastructure and the development of human resources" (Lake Balaton Development Council n.d.).

The unprecedented crisis at the beginning of the 21st century prompted the Lake Balaton Development Coordination Agency to join hands with the International Institute for Sustainable Development and the United Nations Environmental Program to launch a comprehensive research and action project in the year 2001. The project was called as: 'Lake Balaton Integrated Vulnerability Assessment, Early Warning and Adaptation Strategies Project' with the short title of the Balaton Adaptation Project (BAP) (Pinter et al. 2008).The project aimed at improving "knowledge on the ecology, the economy and the society of the Lake Balaton Region. It also aimed to contribute to the development of adaptation measures and improved policies" (Bizikova and Pinter 2009; Pinter et al. 2008; Horvath 2011). The project involved use of highly relevant research methods such as Indicator development, scenario analysis and modeling. The target issues were identified as: (a) Water quality improvement, (b) Water quantity control, (c) Land use change, (d) Biodiversity conservation, and (e) Demographic change (Lake Balaton Development Council n.d.)

4.2 Base Model for Understanding the System Based on Prior Research

4.2.1 Introduction

The previous chapter presented a review and analysis of the literature on the methodological tools that are of interest for this research. Based on the understanding gained through this review and analysis, the research was conducted employing these methodological tools. The main tool used in the research is the tool of system dynamics (SD) modeling. The SD modeling was done using the method of Participatory System Dynamics (PSD) modeling. However, the first step was to make use of the inputs that can be drawn from the previous research on the problems in the Balaton region, using the two tools of scenario planning (SP) and indicator systems (IS). The inputs from this research were used to build a system dynamics model of the socio-ecological system in the watershed region of Lake Balaton.

4.2.2 The Base model for Understanding the System

This section presents the model that was built using the inputs drawn from the available reports, presentations, and articles based on the research conducted previously on the situation in Balaton region using the two research tools, namely, Scenario Planning (SP) and Indicator Systems (IS) (Pinter et al. 2008; Bizikova and Pinter 2009; Lake Balaton Development Council n.d.; Straten and Somyodi 1980).

The first diagram, Figure 4.4, talks about the broader picture of how 'Changes in Climactic Conditions' affect the ' Total Income (of the Region)'. As mentioned before, climactic changes are a big concern in the region, which include changes in temperature, patterns and the temporal distribution of precipitation (includes both, rain and snow). The climatic changes of concern also include extreme events pertaining to precipitation and temperature. The main source of income for the Balaton region is tourism. 'Attractiveness of the Region for Tourism' is, hence, an important factor (or variable in the model) and is affected significantly by the 'Changes in Climactic Conditions'. 'Changes in Climactic Conditions' also result in 'Changes in the Types of Vegetation' and, thus, the 'Agricultural Productivity'. As agriculture is the second highest income generating activity, it also is a key factor determining the 'Economic Conditions of the Region'. Issues related to 'Water Shortage' and 'Water Quality' significantly affect both tourism and agriculture.

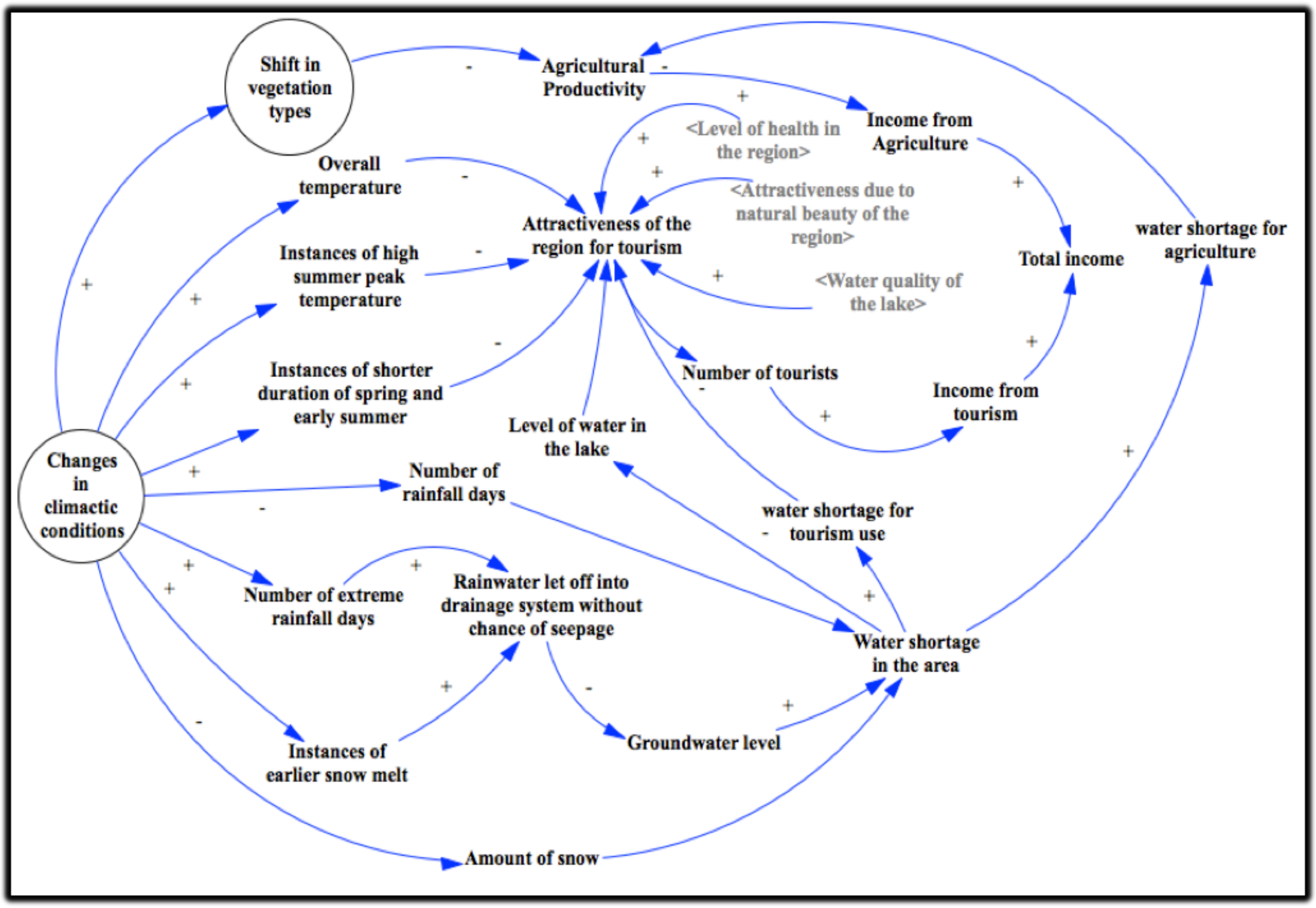

Figure 4.4: Connections between Changes in Climactic Conditions and the Total Income of the Region

The second causal diagram in Figure (4.5) talks about the 'Health' subsystem. As most of the inhabitants and tourists are elderly, health is a major concern. Changes in climactic conditions lead to health concerns of elderly people, extreme heat or storm related health issues and accidents and respiratory illnesses. The third causal loop diagram in Figure (4.6) talks about the biodiversity aspects, the main concern being the nutrient concentration in the lakes, affecting not only the water quality but also the biodiversity balance of the lake through factors such as growth in the population of blue green algae, decreasing fish population, and bird population. Both these factors, the 'Water Quality' and 'Biodiversity', affect the natural beauty of the lake and the region and, hence, also affect the 'Attractiveness of the Region for Tourism due to Natural Beauty'. This has implications for economics of (or income from) tourism. The 'Nutrient Concentration' is affected by the factors such as, 'Phosphorous Load', 'Sewage Discharges', 'Residence Time of the Lake Water', and 'Erosion Potential of the Surrounding Region'.

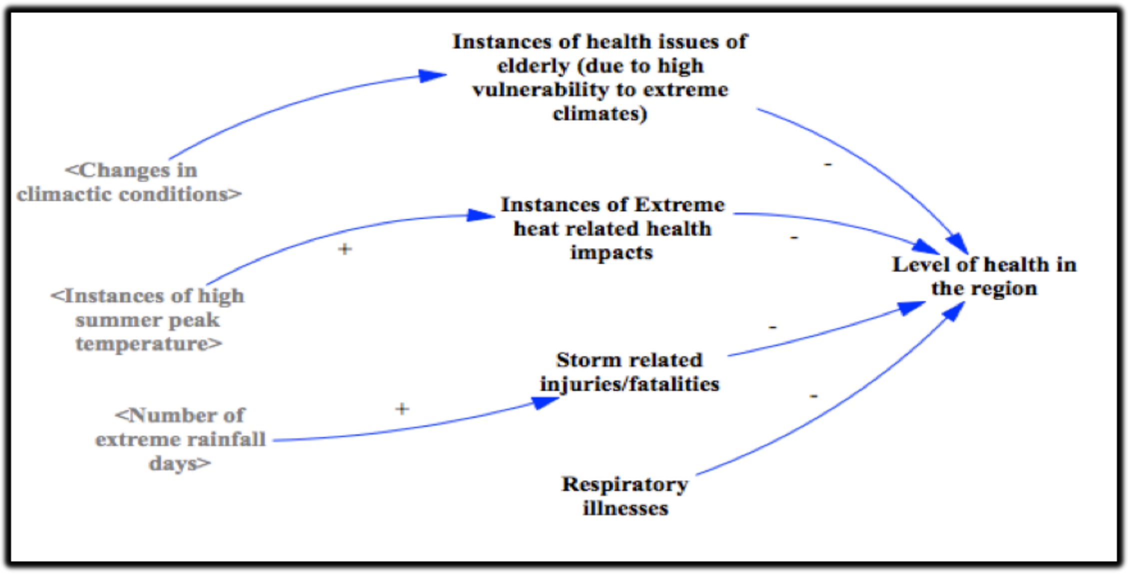

Figure 4.5: The Health Subsystem

It needs to be mentioned here that this exercise of structuring system dynamics model, using the inputs from previous research helped the research immensely, mainly in the following manner:

(a) It helped the researcher understand and appreciate the complexity of the reality of the SES, which, in turn, helped him envisage the need to think in terms of a meta-model and conceive its structure.

(b) It helped the researcher to understand the substantive meaning and nuances of the input provided by participants during the PSD sessions.

(c) It helped the researcher to organize the huge diversity of inputs and metal models of the represented of diverse stakeholder with diverse backgrounds (and disciplines) and interests.

However, in order not to influence their thinking, these models were not shared with the participants in the PSD exercises.

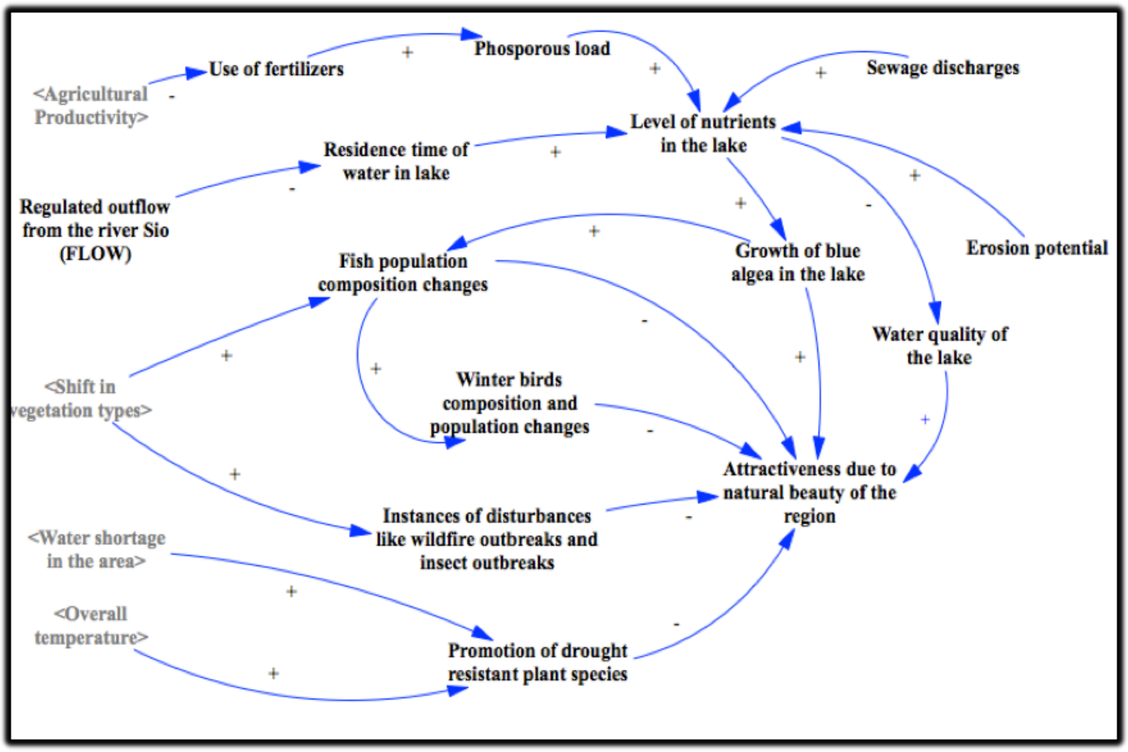

Figure 4.6: The Biodiversity Subsystem

Chapter 5: Lake Balaton Watershed: Conceptual Model

This chapter contains the report of the element of the research to which major portion of efforts were devoted. It contains description of the pilot-level conceptual system dynamics model of the social-ecological system (SES) of the Balaton watershed region. The first section in the chapter provides the general introduction to the model, while the second describes and discusses one of the two major components of the model, namely, the meta-model. The other major component of the model comprises the conceptual system dynamics model disaggregated in eight layers. The remaining eight sections of the chapter provide description of findings and discussion on analysis of the data that is integrated in the conceptual model on the eight layers of the model. The findings and analysis presented in this chapter entirely depend on the primary data obtained from the participants through interactive sessions that employed the Participatory System Dynamics Modeling method.

5.1 Introduction to the Model

The understanding gained from the review and analysis of literature pointed out one major lesson that the SES of the Balaton watershed is an immensely complex system. The preliminary version of the model that was constructed using the inputs from previous research also confirmed this lesson. With this in mind, a complex meta-model of the SES as a whole is conceived. This meta-model is presented in the first section of this chapter. The complex meta-model of the SES is envisaged as composed of eight layers that are interconnected. Each of the layers represents a critical theme in the SES. These layers are (a) Climactic conditions, (b) Water Level, (c) Water quality, (d) Biodiversity, (e) Demography, (f) Politics, Economics and Conflicts, (g) Tourism and Perceptions and (h) Shoreline Development. Each layer presents a web of interrelationships in a number of variable pertaining to the theme represented in the model. Apart from the complexity of the web of interrelationships on each of the layer, the complexity of the models of the overall SES also comes from the interconnections among or across these layers.

The subsequent sections of the chapter present these eight components of the meta-model in each of the eight layers. It needs to be reiterated here that all the data used in these sections is drawn from the PSD session conducted with the representatives of stakeholders in the SES. Each section contains two main elements: (a) description of findings based on the data gleaned through the PSD sessions and (b) discussion of the analysis based on the findings. The findings of the research are presented in terms of: (a) the central problem and other issues pertaining to the theme of the layer, (b) various variables that have relevance to behavior of the SES around the theme represented in the layer, (c) various causal relationships among the variable represented on that layer, and (d) connections of the layer with the other layers. The analysis in each section is presented in terms of: (a) the causal lop diagrams, (b) the stock and flow diagrams (if any), (c) the feedback loops within the layer or across other layers, (d) possible points of interventions. It needs to be noted here that the causal relationships are not descried here separately, but they are part of the discussion of causal loops in the layer.

5.2 Structure of the Meta-model

This section presents the meta-model of the complex socio-ecological system in the watershed region around Lake Balaton. As mentioned in the previous section, the idea of the meta-model is proposed in order to enable the effective handling of the complexity in the SES. This section explains the structure of the meta-model and how it will be used to construct the model.

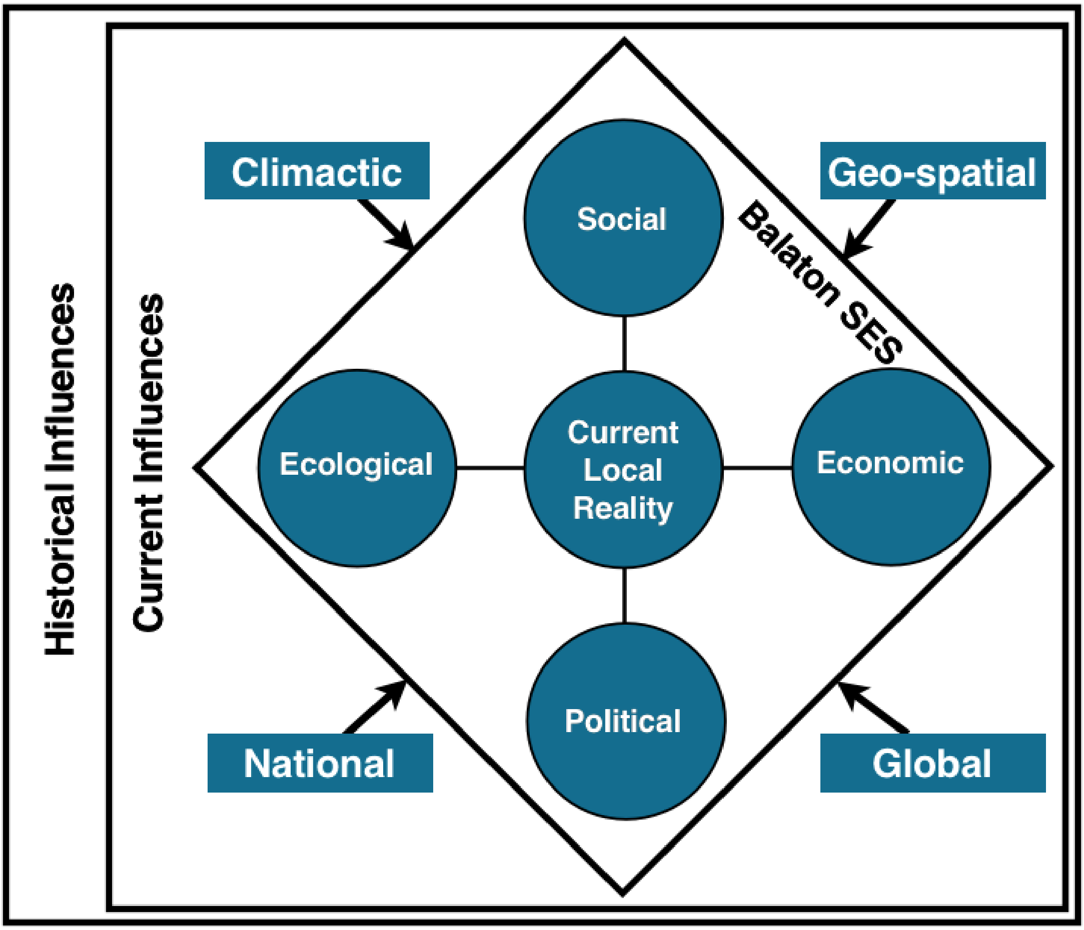

Figure 5.1: Meta-model of the Balaton SES

The socio-ecological system (SES) in the watershed area of Lake Balaton is characterized by extremely complex interrelationships. This complex SES is envisaged in the form of a meta-model, which is depicted in Figure 5.1. As the first step in constructing the meta-model, the local reality of the SES of the Balaton watershed region is seen as composed of four spheres, namely, social, ecological, political and, economic, even though the 'social' category subsumes the 'political' 'economic' and 'cultural'. However, in the meta-model of the Balaton SES, it is felt to be useful to consider the social, political, and economic spheres as distinct spheres. This is because each of these three spheres influences the system significantly. Apart from these four spheres, which are part of the local reality of the SES, the meta-model also considers influences that are external to the SES. These external influences are first divided along the temporal axis in two groups, namely, current influences and historical influences. In the second level of classification, each of these temporal categories is further classified in four types of influences: (i) Global, (ii) National, (iii) Climatic, and (iv) Geo-spatial. It needs to be noted that the first two of these are related to scale, whereas the latter two are more substantive in nature. Thus, the two typologies combine to give, in all, eight different types of external influences acting on the SES.

These different spheres of the reality as well as the eight major types of influences make the Balaton model very complex. It is expected that there would be multiple levels of feedbacks and connections, not to mention the large number of variables and an even larger number of causal links among these variables. Thus, there is a need to simplify the model.

The first decision that was made to simplify the model was not to consider all the four sub-categories of the historical influences as well as the current-global influences, as they were seen as somewhat 'remote', disconnected and difficult to capture in terms of causal relationships, even though some of these were mentioned by participants in the PSD sessions. The second strategy that was used to make sense out of the complex reality was to envisage the model as made of different components, each presented on a layer.

The major themes that emerged from the literature review and PSD sessions with the respondents include: (i) Climactic Conditions, (ii) Water Level, (iii) Water Quality, (iv) Biodiversity, (v) Demography, (vi) Politics, Economics and Conflicts, (vii) Tourism and Perceptions and (viii) Shoreline Development. These eight themes are devised in such a manner that each of them has one central problem each and a corresponding causal-loop diagram. In other words, these theme-wise causal-loop diagrams are layered in the model in eight layers (each for a theme). These layers (and the causal loop diagrams on each of these layers) are connected through causal linkages among variables that are common to these layers. Further, there are feed back loops within each layer (i.e., intra-layer) and even across the layers (inter-layer). Figure 5.2 depicts the eight themes and corresponding layers in the meta-model, which are connected with each other.

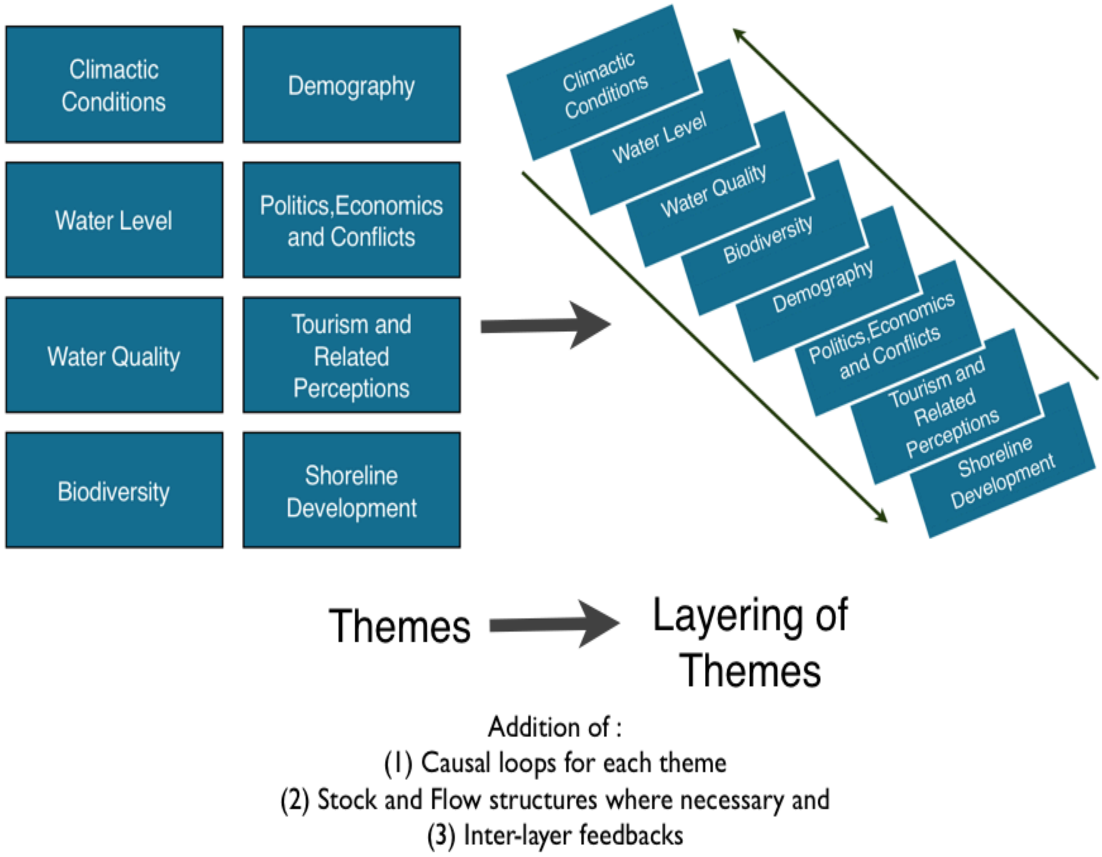

Figure 5.2: Layering of Themes

Some of these eight themes have fairly simple causal loop structures, whereas some have very complex ones. Some aspects or variables that are modeled in some layers are purely perception-driven and complex, while some have factual connections.

It needs to be noted that the model built through this thesis has certain limitations. As mentioned before, the model does not consider the 'remote' i.e., current-global influences as well as all types of historical experiences. Second, the modeler has remained strictly restricted to inputs received from two sources mentioned before: (a) previous research, and (b) PSD sessions. Inputs were not accepted from any other source, including the modeler's own understanding. This puts in severe limitations on the model, as the understanding of the reality of the Balaton SES gained through inputs from these two sources would have some gaps and anomalies.

Further, the model contains some variable that need to be defined and included in the causal loop diagrams. The model, even at the end of this thesis research remains conceptual, which needs to be quantified and simulated. This would require that the qualitative variables be made amenable to quantification (through use of proxy variables).

However, all these limitations were accepted as given in view of the limited time and resources available for this research for a master's thesis. In that sense, the model is a limited and hence called here as 'pilot' model.

5.3 Findings and Analysis of Layer 1: Climactic Conditions

This section presents the first layer of the model of the SES of the Lake Balaton watershed region. It is devoted to the theme of Climatic Conditions, one of the prime concerns for the Balaton region. As mentioned before, this section will present the description of the findings and discussion on analysis related to various aspects related to the theme of Climatic Conditions.

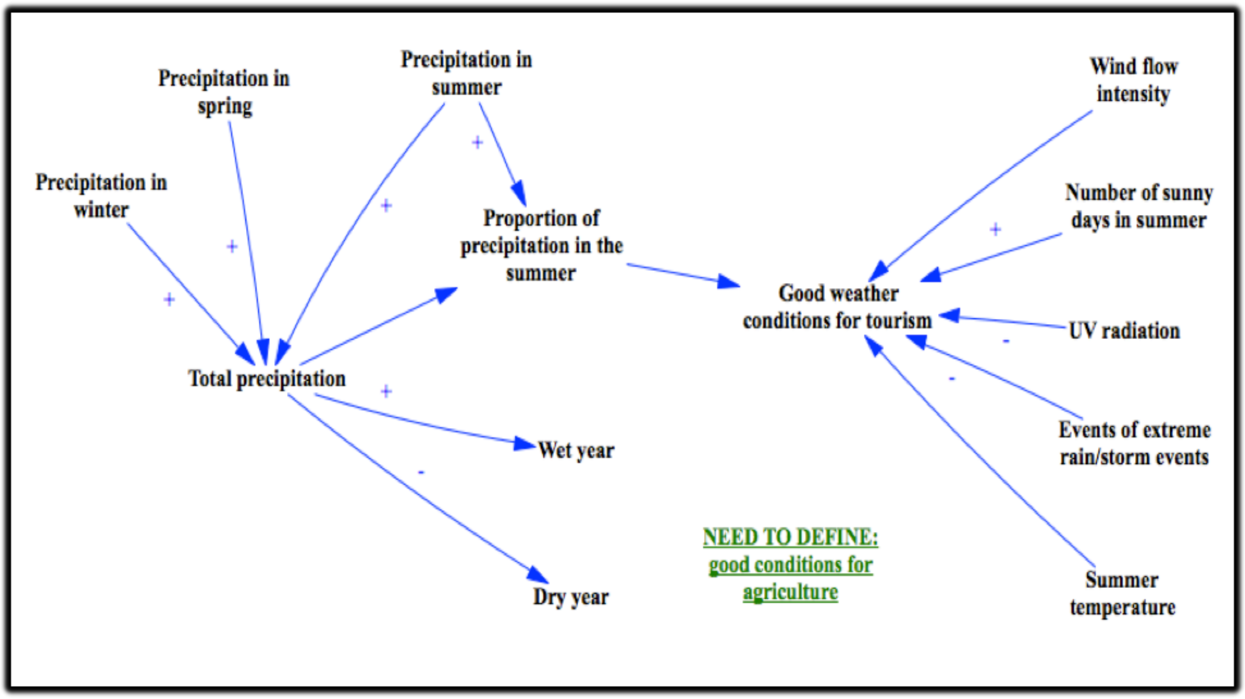

Figure 5.3: Climactic Conditions Layer

Among the changes in climactic conditions in the Balaton region, precipitation is the major concern. It was mentioned during PSD sessions that even though there might be a slight decreasing trend in the total precipitation, it is the extremities (or extreme events) pertaining to precipitation that is the major point of concern. In this context of extremities, the region has experienced consecutive extreme dry years followed by extreme wet years in the past decade.

Not only the amount of precipitation, but also its seasonal distribution that has been experiencing extreme changes. 'Wet Years' and 'Dry Years' are more frequent and affect decisions related to water management and are, thus, critical variables in the model that connect this layer to the other layers. The variables of 'Wet Years' and 'Dry Years' are connected with the switch of 'Management Decisions Regarding Water Level Management' in the layer of 'Water Level' in the model.

There is also the need to define the variables of 'Good Conditions for Tourism' and 'Good Conditions for Agriculture,' as they are not only the two most important economic activities, but also are closely connected with the climate. Although 'good weather conditions for agriculture' was mentioned, but not defined in the PSD sessions, the variable of 'Good Weather Conditions for Tourism' was discussed in considerable detail.

There are other variable related to climate, the changes which affect tourism, apart from those related to precipitation and its distribution. These include: 'Summer Temperatures', 'Number of Sunny Days in the Summer', 'Wind Flow Intensity', 'Increasing UV Radiation', and 'Increased Number of Extreme Events' (like storms). The variable 'Good Weather Conditions for Tourism' is connected to the layer of 'Tourism and Perceptions' and has major impacts on the economic aspect of tourism. There are no feedbacks yet identified that are only on this layer of the model, although these variables and their effects cascade into the other layers of the model through different inter-layer feedback loops. Similarly, there are no points of intervention identified on this layer, as there is an assumption that the 'Changes in Climactic Conditions' are given, and constitute the central problem. There could be no solutions on the local level to address this central problem directly, apart from the adaptation options, which can be put into action in connection with related issues.

5.4 Findings and Analysis of Layer 2: Water Level

The water level in Lake Balaton is one of the major issues of concern for the region. This makes the "Water Level (in the Balaton Lake)" a major theme in the model of the SES. It is connected to all other layers through inter-layer connections (some of them are part of inter-layer feedbacks) affecting a significant part of dynamics and behavior of the overall SES of the Balaton region. Moreover, it also is one of the themes (or layers) that gave rise to large number of suggestions for interventions during the PSD sessions.

The map of the Lake Balaton watershed presented in Chapter Three 'Figure 3.1: Catchment area and river system of the Lake Balaton', shows the course of water through various water bodies, such as the two lakes (viz., Lake Balaton and Lake Kish-Balaton) the rivers (including the river Zala which is mentioned here) and the Sio Canal. This is converted into the central stock and flow structure for this layer as shown in Figure 5.4.

The central problem on this layer stems from the shallow profile of the lake., which allows only 110 cm of water depth of water. It can accommodate up to 120 cm of water from the lowest point of the lake, before it starts to flood the surrounding areas, leading to flood related damage. This can be a major issue in wet years and would lead to substantial economic damages around the shoreline, especially on the low-lying southern shore.

In dry years, the lake water evaporates faster due to the shallow profile and the water cover decreases substantially, leaving considerable area of the lakebed exposed. This can lead to serious adverse impacts on biodiversity, water quality, and tourism that could cascade into other layers of the model. This layer contains one of the central 'stock and flow diagrams' of the model. It connects not only the issues related to the water quantity (or level), but also the dynamics around management of the water level.

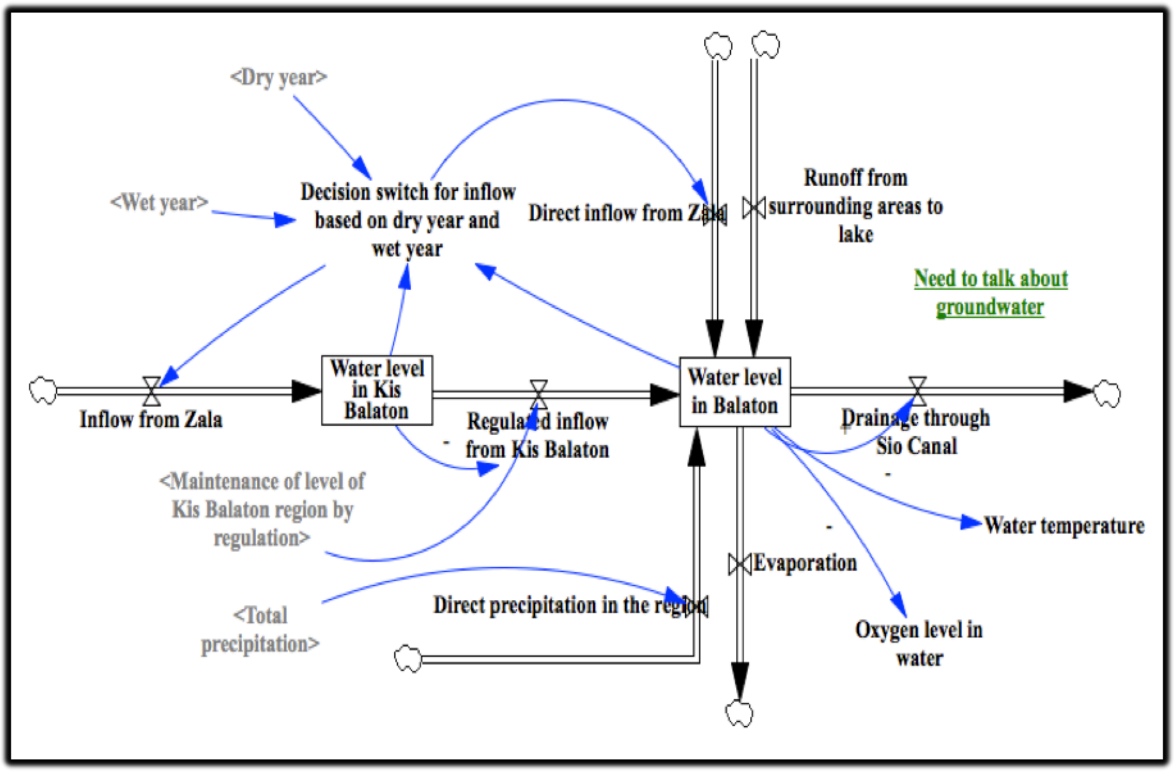

Figure 5.4: Water Level Layer

The major inflow of water into Lake Balaton is from the River Zala, but through the small lake of Kis-Balaton (meaning small Balaton), which is on the upstream side of the main Balaton Lake on the river Zala. Thus, the quantity of the water that flows into Lake Balaton and its water level are critically dependent on the water that flows through Lake Kis-Balaton into the bigger lake. It is very important to note that Kis-Balaton Lake, being a reclaimed wetland, is a 'biodiversity-hotspot' as per the international regime under the Ramsar Convention. There are strict regulations about the maintenance of the water level in Kis-Balaton level monitored by the agencies at the European level.

Kis-Balaton Lake also plays a critical role in the maintenance of the quality of water in Lake Balaton, as it reduces the nutrient concentration of the Zala water (and thus improves the quality of the water) before it flows into Lake Balaton. Regulating water inflow through Kis Balaton involves critical and important management decisions. In the case of a dry year and water shortage in Lake Balaton, Kis-Balaton Lake can be technically bypassed and the water can be directly brought into the Balaton Lake from the River Zala using a canal. However, this would have implications for the water quality in Lake Balaton, as it would be fed with the Zala water from the River Zala that is of inferior quality. This factor influences the decision to bypass the Kis-Balaton. Further, the biodiversity-related regulations pertaining to the water level in the Kis-Balaton Lake also influence the decision related to bypassing the Kis-Balaton Lake. As against this, in the case of a wet year, there can be an option of storing water in the Kis Balaton. These factors result in smaller feedbacks between the inflows and outflows of the two lakes.

The outflow from Balaton streams into the Sio-canal that meets on the river Danube on the downstream side. This is an artificial canal, and needs careful management. It also needs repair and rebuild, as it is in a somewhat deteriorated state at present. The capacity of this canal to carry water has decreased substantially, due to disrepair, and, thus, it causes the problem of flooding of the adjoining areas, when there is increased water flow through the canal, especially in wet years. The canal is regulated through a sluice gate, and thus the outflow from Lake Balaton in the canal is also a management decision.

There are other variables in this layer that connect it to other layers. These include: 'Water Temperature' and 'Oxygen Content'. There was a mention of groundwater in the PSD sessions but not in terms of causal linkages. This is the area that needs to be explored in future research. The major point of intervention on this layer is the decision switch related to water management based on whether the year is a dry year or a wet year.

This discussion on different elements of the layer and its multiple connections with other layers makes this layer one of the most important layers of the model.

5.5 Findings and Analysis of Layer 3: Water Quality

The theme on the next layer is 'Water Quality'. This has been an issue, historically, but now, according to the participants in the PSD sessions, it is not considered as grave an issue as the issue of 'Water-Level'. The main concern expressed in this connection was over the variable of 'Water Quality Desired for Tourism'. This focus on tourism makes it necessary to distinguish this variable from the variable of 'Water Quality Desired for the Environment.' In fact, both of these variables are dependent on the variable 'Nutrient Concentration in the Lake Balaton.' While the connection of the 'Nutrient Concentration in the Lake Balaton' with the variable of 'Water Quality Desired for the Environment' is articulated on this layer, its connection with the variable of 'Water Quality Desired for Tourism' manifests through the other layer, via the variables of: 'Area under Algae Cover,' 'Increase in Pathogenic Bacteria,' and 'Invasive Fish Dying Period'. It needs to be noted that the variable of 'Nutrient Concentration in the Lake Balaton' depends on the nutrient content of different inflows into the lake, and is governed largely by the nutrient content of inflow from the Kis-Balaton, as this smaller lake acts as a natural filter.

As mentioned before, the variable of 'Water Quality Desired for Tourism' is closely connected with the layer representing the theme of 'Biodiversity'. In addition, this layer has many connections and feedbacks from other layers, especially the layers of 'Water Level' and the 'Biodiversity' layer.

Further, there is a need to dwell deeper on the issue of 'Phosphorous Loading' and its connection with the variable of 'Nutrient Concentration'. This is because, in some of the interactions during the PSD sessions, these two issues were used interchangeably, as though the main point of nutrient concentration was phosphorous. This issue needs to be handled in future research.

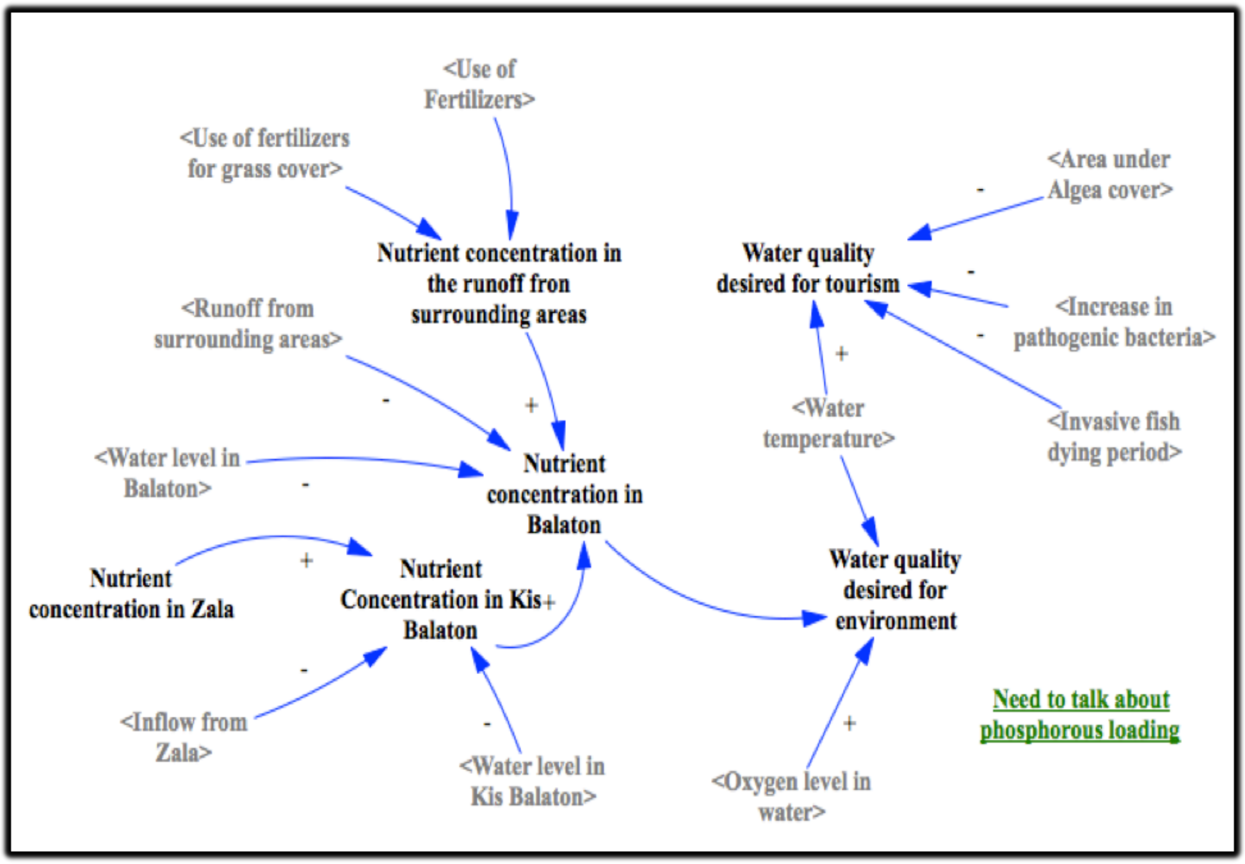

Figure 5.5: Water Quality Layer

5.6 Findings and Analysis of Layer 4: Biodiversity

The Biodiversity layer is a very complex layer and there will be a need to break it down into parts, in order to describe and discuss the issues involved in lucid manner. The major issues related to biodiversity are: (a) destruction of reed banks, (b) growth of toxic blue-green algae, (c) changes in fish populations, (d) changes in bird population and, (e) changes in population of the invasive species. All of these issues are affected by three variables from the layer of 'Water Level': (a) 'Water Level in Lake Balaton', (b) 'Oxygen Level in Lake Balaton' and (c) 'Water Temperature'.

One of the main concerns related to biodiversity in the lake pertains to the blooming of the toxic blue-green algae in the lake. The algal bloom, as shown in Figure 5.6, is connected with the 'Nutrient Concentration in the Lake', a variable coming from the 'Water

Quality' layer. The issue of algal bloom cascades back into the 'Water Quality' layer and affects the variable of 'Water Quality Desired for Tourism', as mentioned before.

The other main biodiversity-related concern that emerged during the PSD sessions was that of the destruction of reed banks. The reed bed cover, as shown in Figure 5.6, faces two kinds of threats of destruction, one being the physical destruction and the other due to pollution and change in the chemical composition of the lake water. The physical destruction is due to illegal developmental activities in the shoreline areas and the resultant reduction of the reed cover. Such destruction creates additional passageways in the reed bed, which allows more 'Wave Action,' which is affected by the variable of 'Wind Flow Intensity'. The illegal shoreline activities also lead to changes in the chemical composition of the lake water along the shoreline and, hence, adversely affect the sensitive reed beds. There are regulations in place for protection and management of the reed-bed cover, which also keep a check on the spread of the reed beds.

The reed beds are critical for biodiversity in the lake, as they provide a good habitat for the wildlife to grow. They act as a spawning area for the native fish population and also a good habitat for small mammals to breed and grow. They also provide shelter and breeding habitat for the native and migratory birds.

'Fish population' is also an important issue, which is closely connected with the issue of the destruction of the reed bed and the issue of population of invasive fish species. It affects the bird population of the region, as the invasive fish are too big for the birds to feed on.

Another important issue is of the invasive fish and molluscs species (Figure 5.7). Historically, the invasive fish species were introduced in the lake for environmental and economic reasons. The silver carp was introduced to feed on the algae growing in the lake. The eels were introduced for economic purposes. The silver carp fishes grow to huge sizes and start dying in the same time period, affecting the water quality in the lake. Both of these fish species cannot spawn in the area, yet there are occurrences of young fish of the species. For explaining these occurrences, there are speculations about the introduction of these fish through the fishponds on the southern bank of the lake. The other aspect of the problem of the invasive species is the mollusc that might have been introduced through the Sio-canal via the Danube from the Black Sea. This is a concern for the region more from the aesthetic point of view

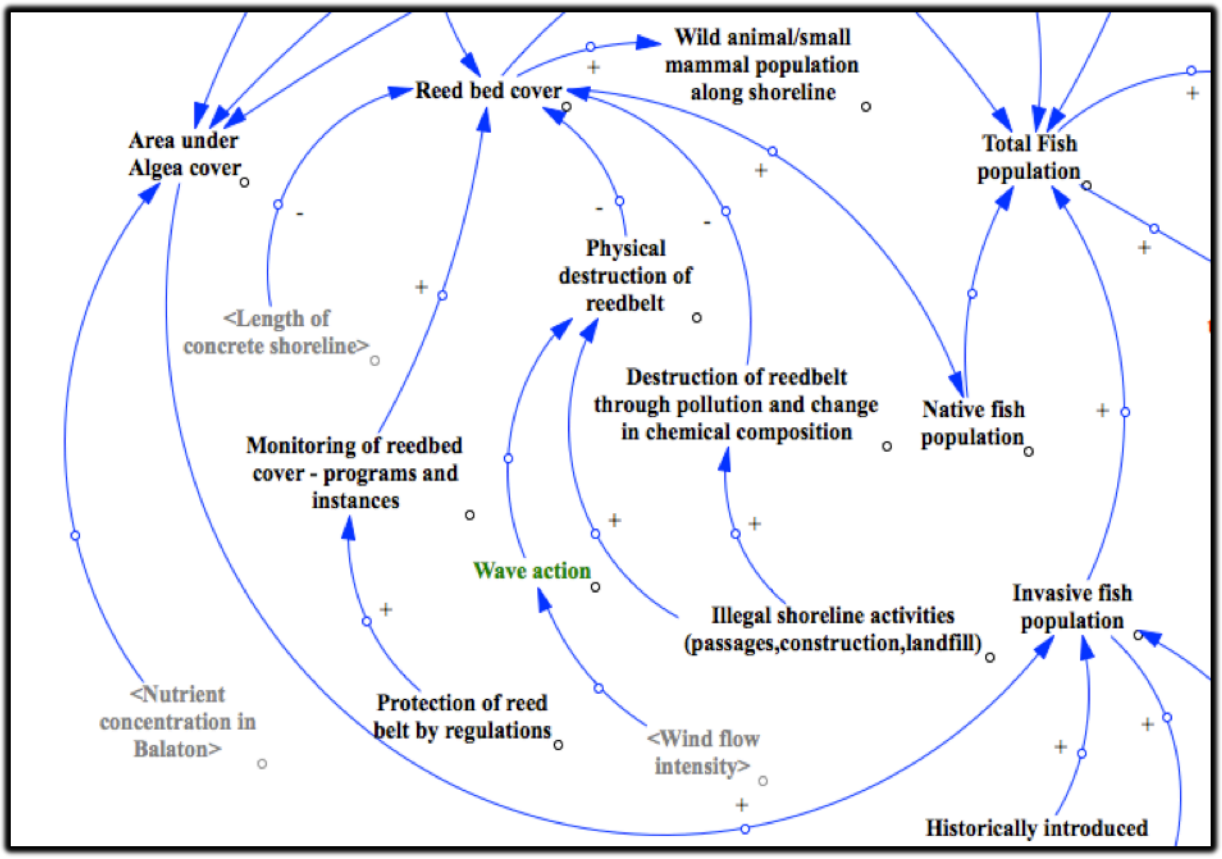

Figure 5.6: Biodiversity Layer Depicting Issues related to Algal Blooms and Loss of Reed Bed Cover

Coming to the lake of Kis-Balaton, it is important from the point of view of biodiversity, as it is the biodiversity hotspot of the region. There are many regulations pertaining to the maintenance of its status. The water level of Kis Balaton is significantly influenced by these biodiversity-related regulations. The role of Kis Balaton to act as a natural filter for inflow into the Lake Balaton is also an important reason to maintain the biodiversity and efficient functioning of Kis Balaton.

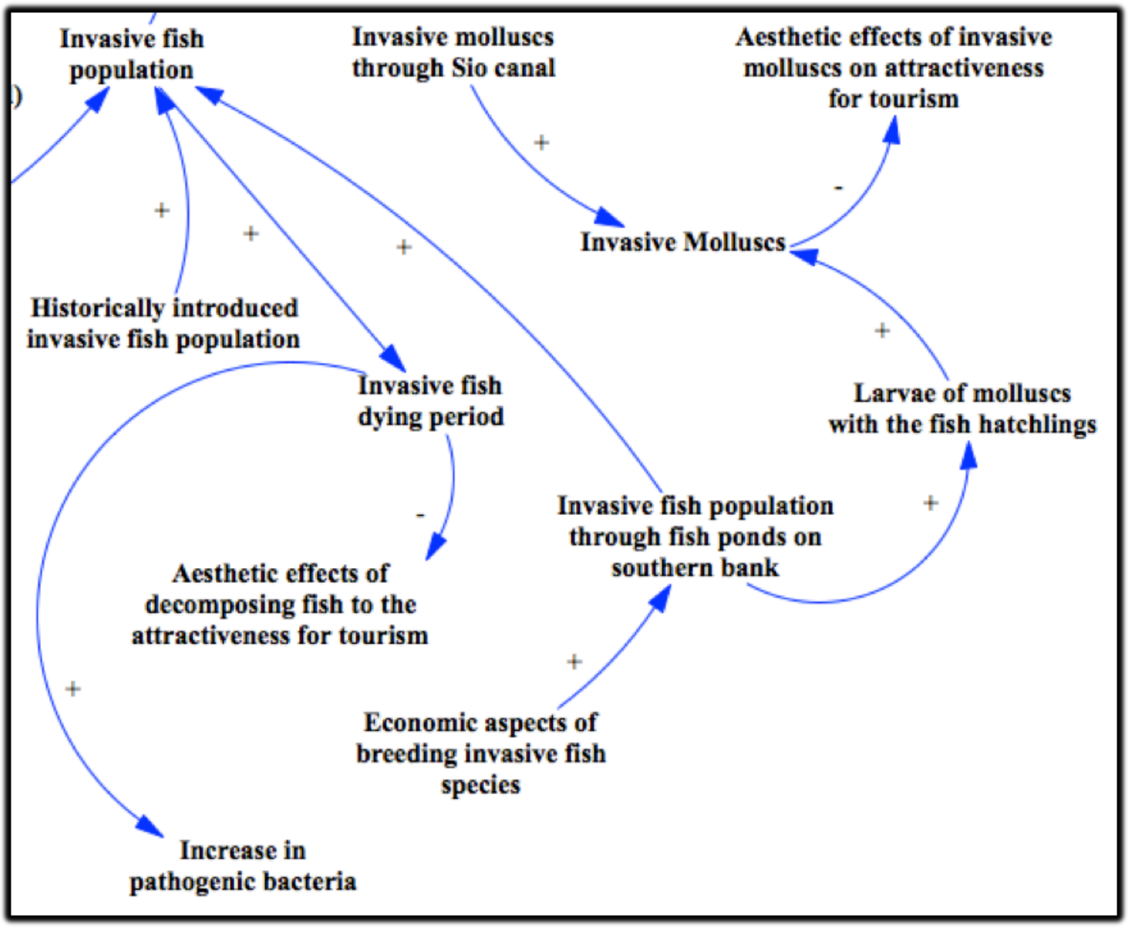

Figure 5.7 Biodiversity Layer Depicting Invasive Species Issue

This layer is connected to various other layers through many inter-layer connections and feedbacks. The feedbacks into this layer come from the layers of 'Water Level', 'Water Quality,' and 'Shoreline Development,' while the feedbacks from this layer go to the layers of 'Water Quality' and 'Water Level'. Biodiversity also has connections with the layer of Tourism indirectly.

5.7 Findings and Analysis of Layer 5: Demography

This layer of 'Demography' contains the second 'stock and flow structure' of the model as shown in Figure 5.8. The layer represents a critical problem of the Balaton SES. The issue of concern here is that of the demographic change and the growing population of elderly people in the region. The model in this layer considers only the permanent elderly inhabitants of the region, and not the seasonal inflow of elderly inhabitants in the summer. A corollary of the issue is migration of the youth out of the region, mainly to bigger cities. Almost all participants of the PSD sessions mentioned this issue in connection with other different aspects of the system. The issue is connected with a few national level issues and also has connections with the issue of disparities between the region and other regions.

Some of the major factors underlying the migration of youth out of the region include better educational opportunities outside the region, better job opportunities outside the region, and heavy dependence of the region's economy on seasonal jobs in tourism activities.

The elderly population, on the other hand, is increasing in the region due to migration from other regions to the Balaton region. Historically, the Balaton region has remained a popular location for second-homes or summer-homes. The owners of these homes arrive in the region in significantly large numbers during the summer months or weekends. The population that invested in these summer homes or second homes is now aging. A large number of these aging owners are moving into the region as permanent residents, due to various factors such as the pleasant climate and landscape, the health-related attractions like the Heviz thermal lake, and adverse economic conditions in the country. To be more specific, some elderly people are moving into the region, as they are giving their city homes to their children who cannot afford to buy properties in the cities due to adverse economic conditions. Moreover, there is a migration of foreigners on permanent basis, who own summer homes in the region as well.

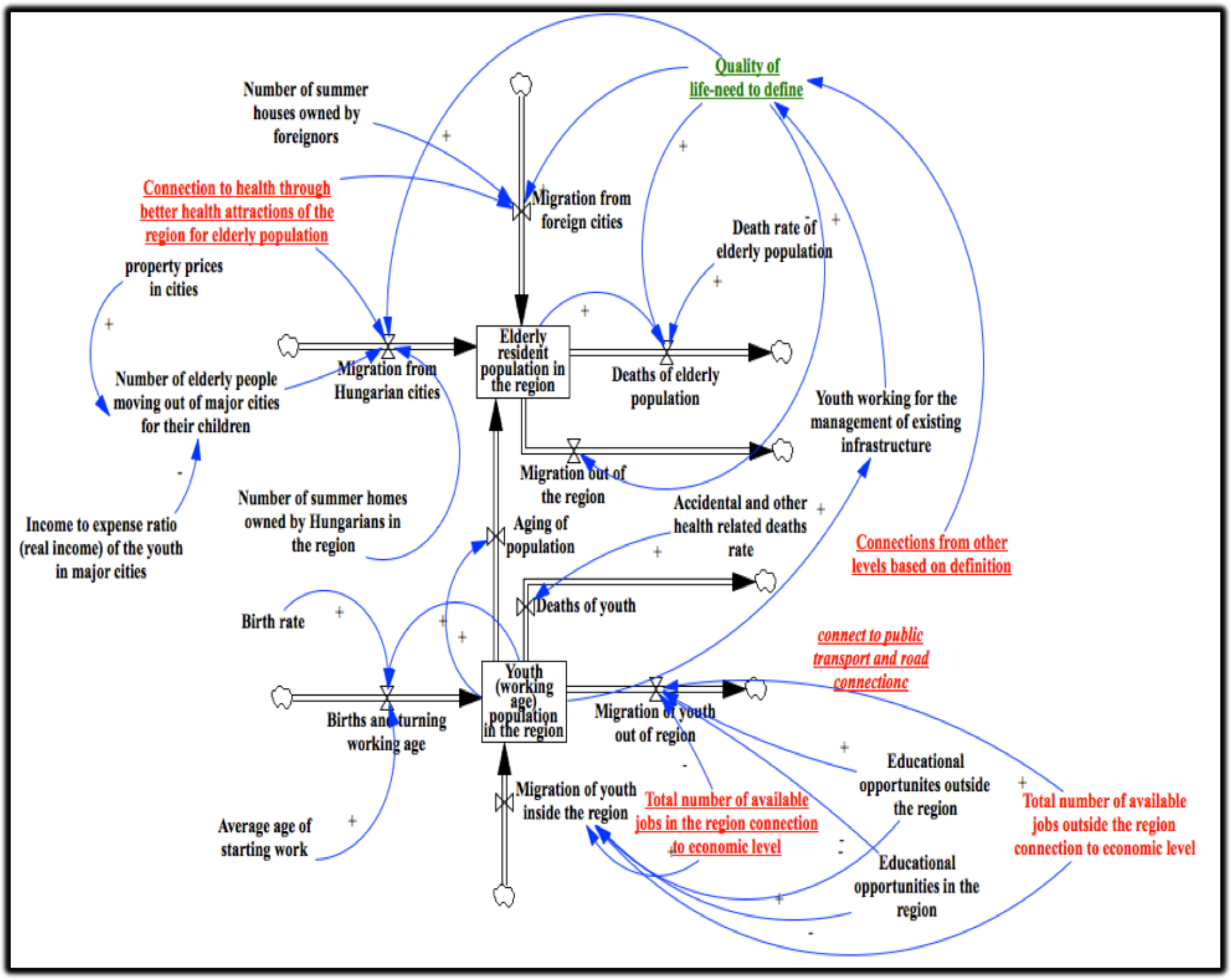

Figure 5.8:Demography Layer

This in-migration is affected by a critical influencing factor, which was called as 'Quality of life' by most of the PSD participants. There is a need to exactly define what this variable of 'Quality of Life' means for the region and its inhabitants. However, the quality of life would certainly depend heavily on the services available and accessible in the region. In order to manage these services, the youth population will have to stay back in the region. This means that the current trend of the migration of youth out of the region, could lead to a reduction in the quality of life, which, in turn, would reduce the migration of both the youth and the elderly into the region. This is a crucial feedback and the PSD participants suggested many interventions to address this issue. Most of these interventions revolved around improving the service sector and enhancing the non-summer tourism industry of the region, in order to provide jobs for the youth beyond the summer months, so that the youth would provide the services to the elderly that are necessary to improve 'Quality of Life'.

5.8 Findings and Analysis of Layer 6: Politics, Economics and Conflicts

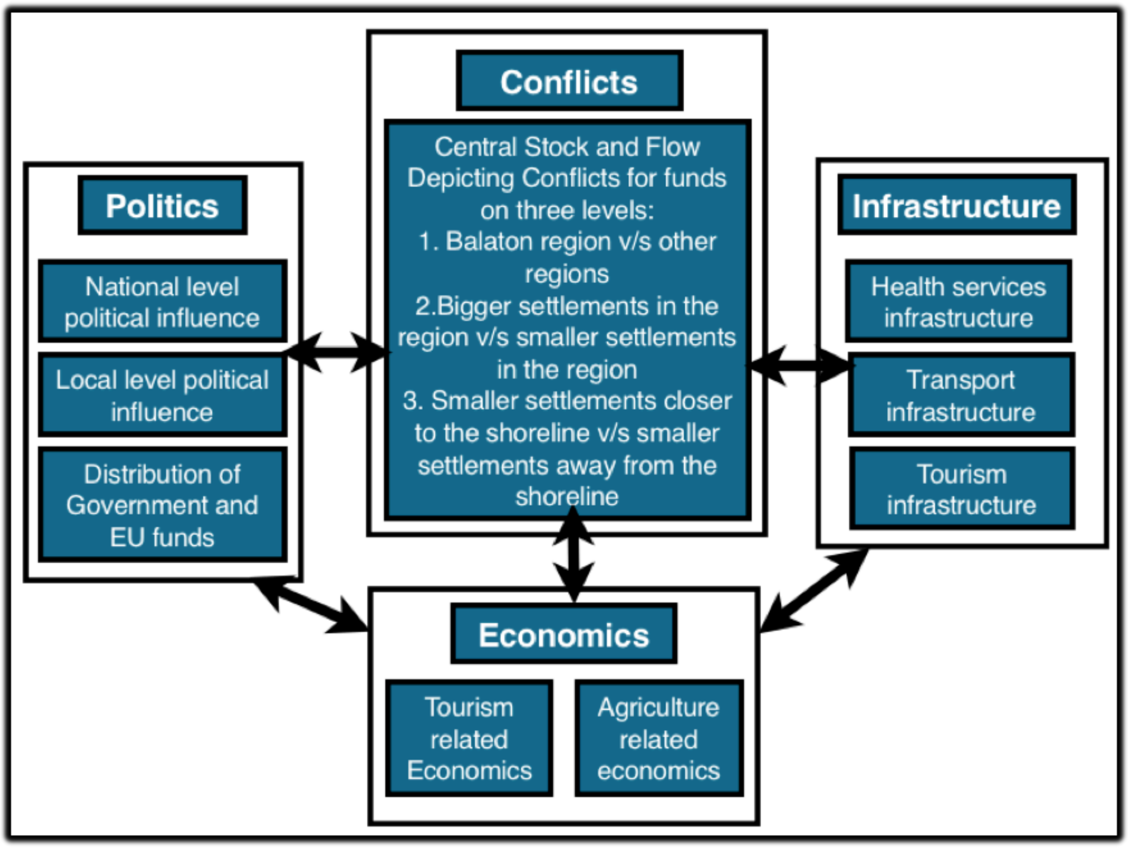

Figure 5.9: Meta-Model for the Politics, Economics and Conflicts Layer

5.8.1 Structure of the Layer

This section covers the layer of the theme: 'Politics, Economics and Conflicts,' which is the most complicated layer in the model. It is necessary to explain the structure of the complex layer before moving into the detailed description of findings (please refer to Figure 5.9). The layer has a 'stock and flow' structure at its center, depicting conflicts for funds on three levels: (a) between the region and other regions, (b) between bigger settlements in the region and smaller settlements in the region, and (b) between the two groups of smaller settlements from the region, those that are closer to the shore and those that are away from the shore. This central conflict-focused 'stock and flow' diagram (or SFD) interacts with three smaller subsystems: politics, economics, and infrastructure. These sub-systems also interact with each other. The three sub-systems have some important elements as depicted in Figure 5.9.

Tourism is a critical and many-faceted subsystem in the Balaton SES. As, in this layer, the focus is on the politics, economics, and infrastructure. It covers only these aspects of tourism activity. The other aspects of the tourism, especially the perception-based aspects are not covered here.

5.8.2 Constructing the Stock and Flow Diagram

The detailed structure of the central conflict SFD is shown in Figure 5.10. The stocks are expressed in terms of the 'funds allocated', rather than the 'funds used'. This is because the political dynamics revolves primarily around allocation of funds rather than their use. The funds come from two main sources, namely, the European Union and the national government. The National Development Agency (NDA) of the country decides the proportion of total EU funds to be allocated to the region, whereas the Parliament decides the proportion of the national funds to be allocated to the region. The decision on the proportion of the allocation of the funds from two sources, first of all, depends on the total funds available from the two sources.

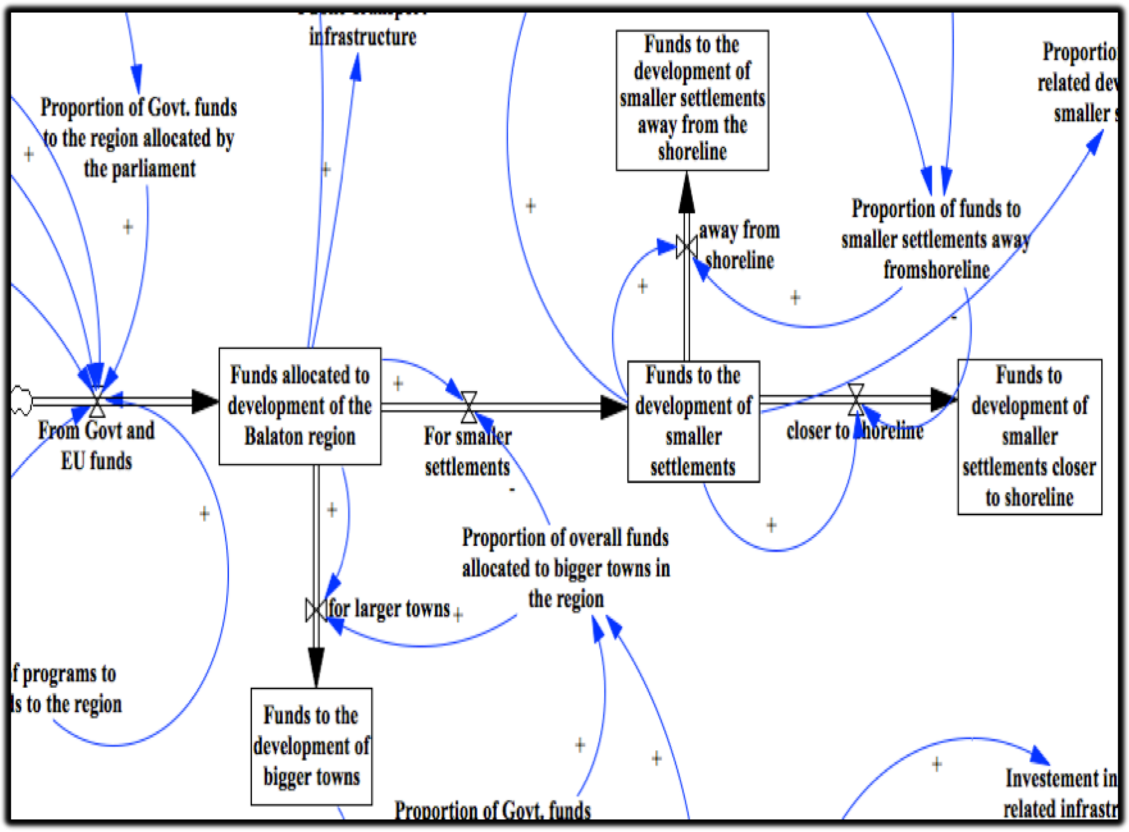

Figure 5.10: Water Quality Layer

The other factors that influence the funds allocation to the region from these two sources include: (a) importance of the region in terms of national income, (b) the willingness of national level political actors willing to take up the cause of the region, and (c) influence of politicians from the region in the parliament who advocate for the development of the region. The 'willingness' and 'importance' are qualitative variables, yet very critical for gaining understanding of the dynamics and drivers of the system. These qualitative variables are reflected in the variable of 'Proportion of Funds Allocated to the Region' and 'Number of Programs to Direct Funds to the Region', which are quantitative and will act as proxies for the qualitative variables. Such qualitative variables are included in the model as they are important in understanding the behavior, but will not be counted in the simulation, as they will be modeled as multipliers with equation 'multiplied by one.'

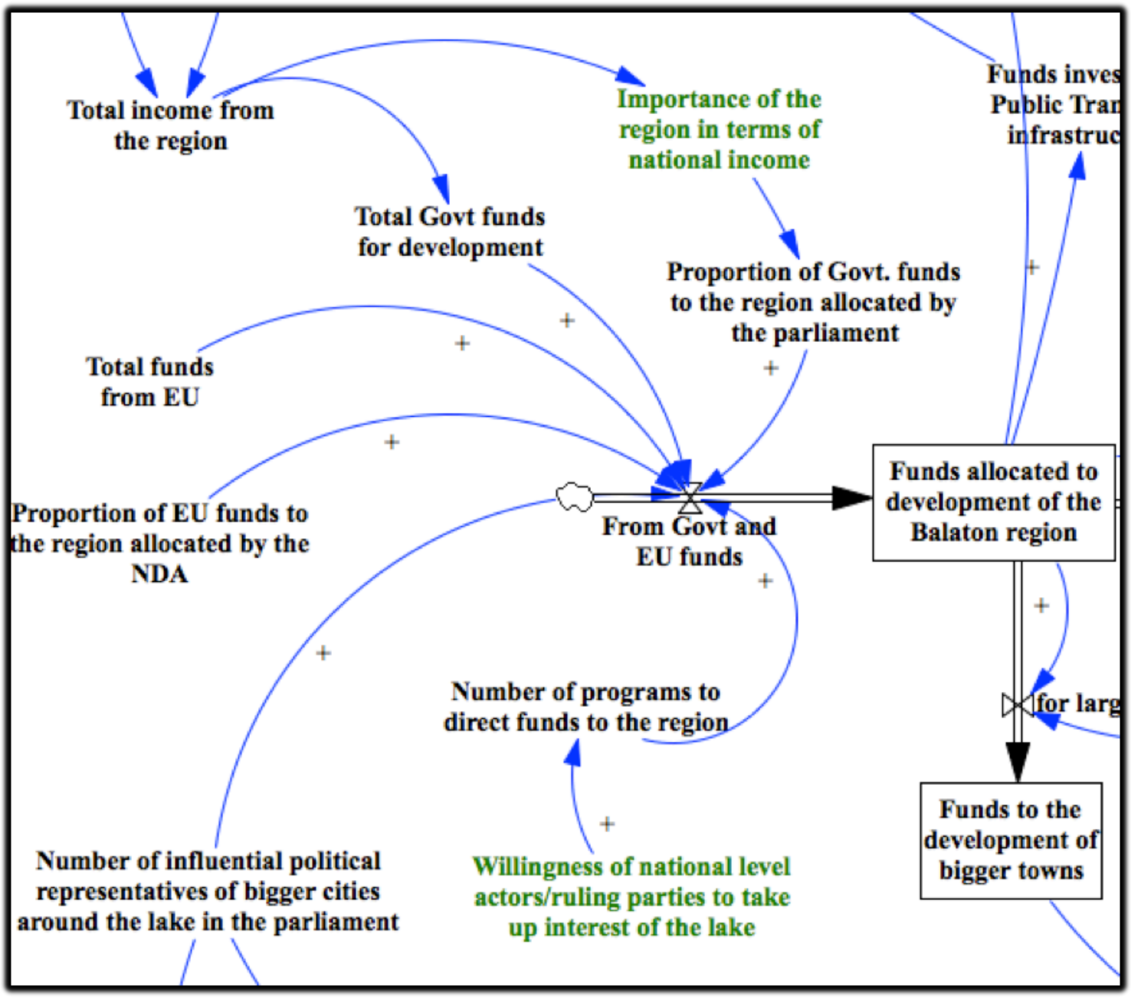

Figure 5.11: Decisions Regarding Funds Allocated to the Region

5.8.3 Conflict Among Different Settlements

The politics underlying the conflict between bigger settlements and smaller settlements is driven by the fragmented representation of the region in the national level politics. The bigger cities have more influence in the political arena, and thus the interests of the politicians from bigger cities prevail in decision-making; as a result, projects from the big cities get more funds. The parliament also affects the decision of the NDA for allocation of the EU funds, so the bigger cities also wield a higher influence on funds coming from EU that are distributed by NDA. Further, the NDA gets more and better project proposals from the bigger cities, as the bigger cities have a higher capacity to launch bigger development projects. As a result, a large proportion of the funds allocated to the region get directed to development projects in bigger settlements (please refer to Figure 5.12)

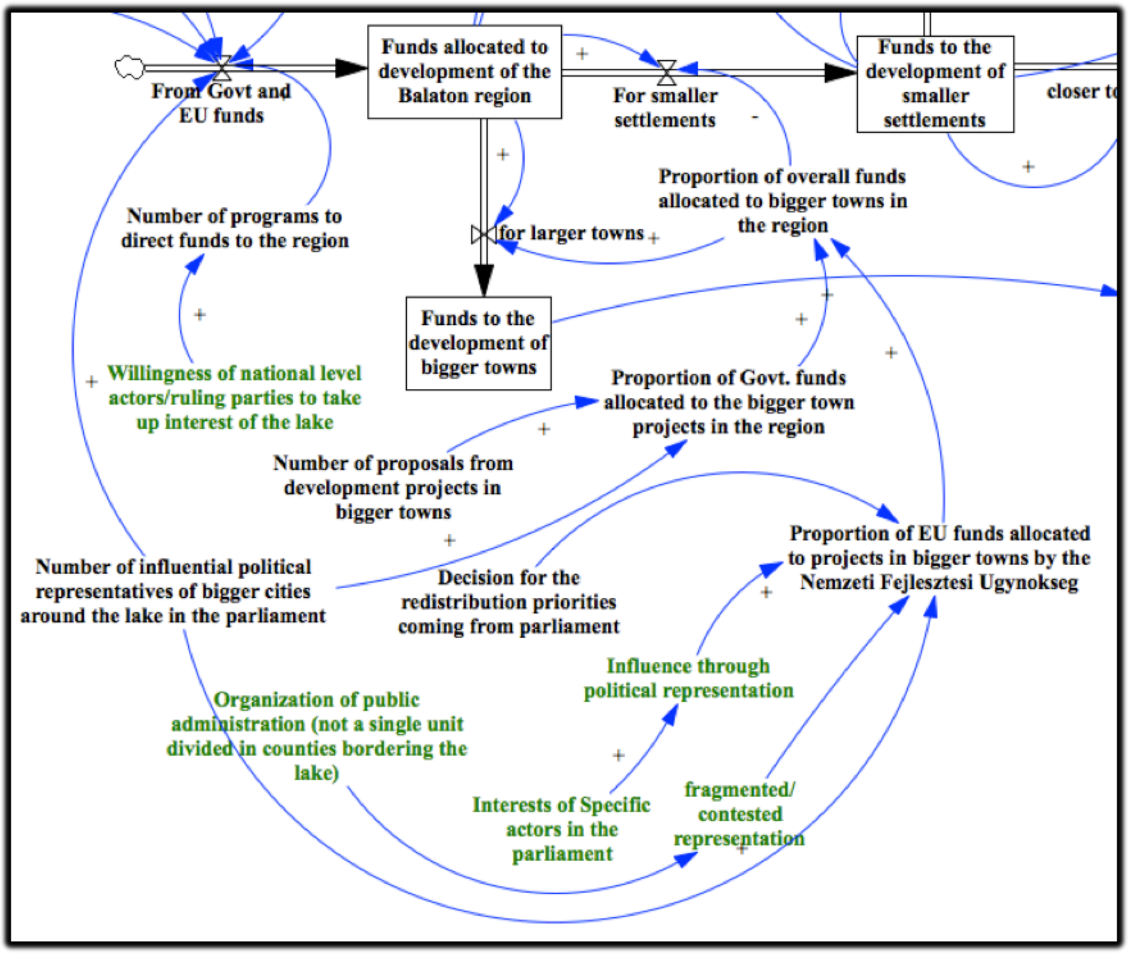

Figure 5.12: Conflict between Bigger Settlements and Smaller Settlements for Funds, The Political Dimension

As shown in Figure 5.13, higher expenditure on projects in big cities fuel infrastructure development in big cities. These bigger settlements, due to the higher flow of funds and number of projects, have better development opportunities and thus better tourism related infrastructure. They also have better transport infrastructure with higher frequency of public transport connections between bigger settlements and cities outside the region. This attracts more tourism and adds to the income from these bigger settlements to the overall tourism income, thus increasing their importance in the economic arena as well. As more tourists visit, the demand for better infrastructure increases and leads to new projects in the bigger settlements. In this way the political and economic dynamics of preference to bigger settlements feedback into each other reinforcing the behavior.

As against this the smaller settlements get less allocation of funds to begin with, and have less influence in the political and economic arena. As they possess less power in both the economic and political sphere, small settlements suffer from a serious disadvantage and disparity in competition with the bigger settlements or cities.

Then there is an added dimension of conflict in the form of conflict between smaller settlements close to the shoreline and the smaller settlements farther away from the shoreline. The smaller settlements away from the shoreline are also adversely affected by economic and infrastructure factors such as (a) lower demand for tourism related infrastructure and (b) poor connectivity and lower frequency of public transport connection to these settlements. In other words, since the public or private transport infrastructure is not established or has lesser frequency, the settlements that are away from the shoreline are less accessible and, as a result, there is less inflow of tourists to these settlements.

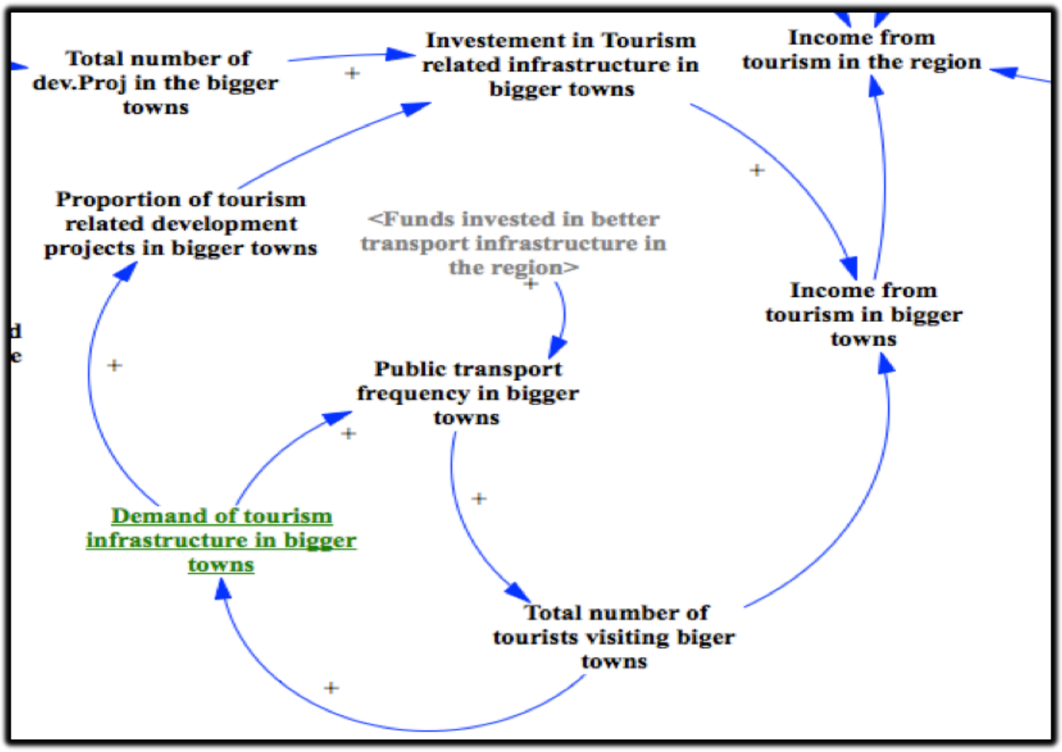

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Figure 5.13: Conflict between Bigger Settlements and Smaller Settlements for

Funds, The Economic and Infrastructure Dimension

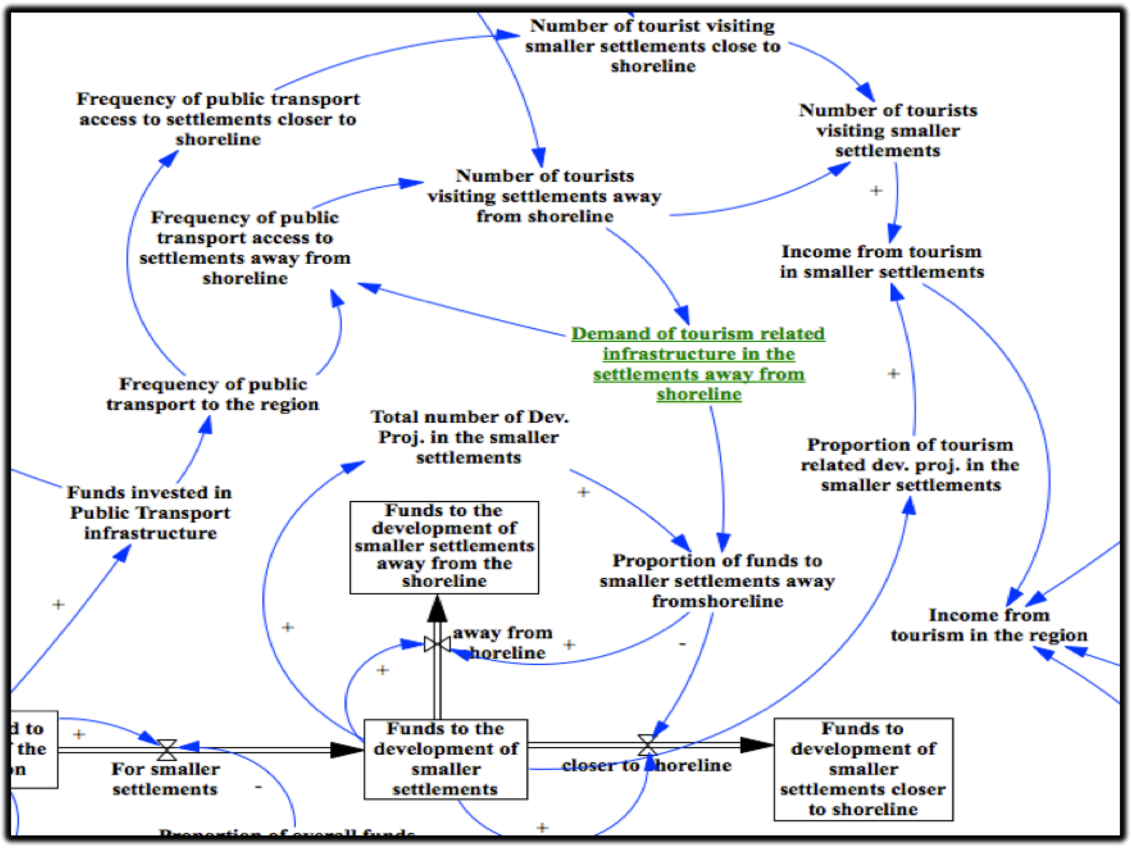

Figure 5.14: Conflict between Smaller Settlements Close to Shoreline and Smaller Settlements Away from Shoreline

5.8.4 Agricultural Activity and Economics of the Region

This layer also refers to agriculture and income from agriculture. Apart from the traditional agriculture, there are vineyards and organic farms in the region. In the past, there was intensive agriculture on the large scale, resulting in the overuse of fertilizers, affecting quality of water. But, after the change in the political regime, in the Balaton region the use of fertilizers decreased due to economic reasons and traditional agriculture took a backseat in comparison with tourism. Vineyards and organic farms are emerging agriculture options. They are seen as desirable, as they not only add to cultural value and human health in the region, but also are strong attractions for tourists.

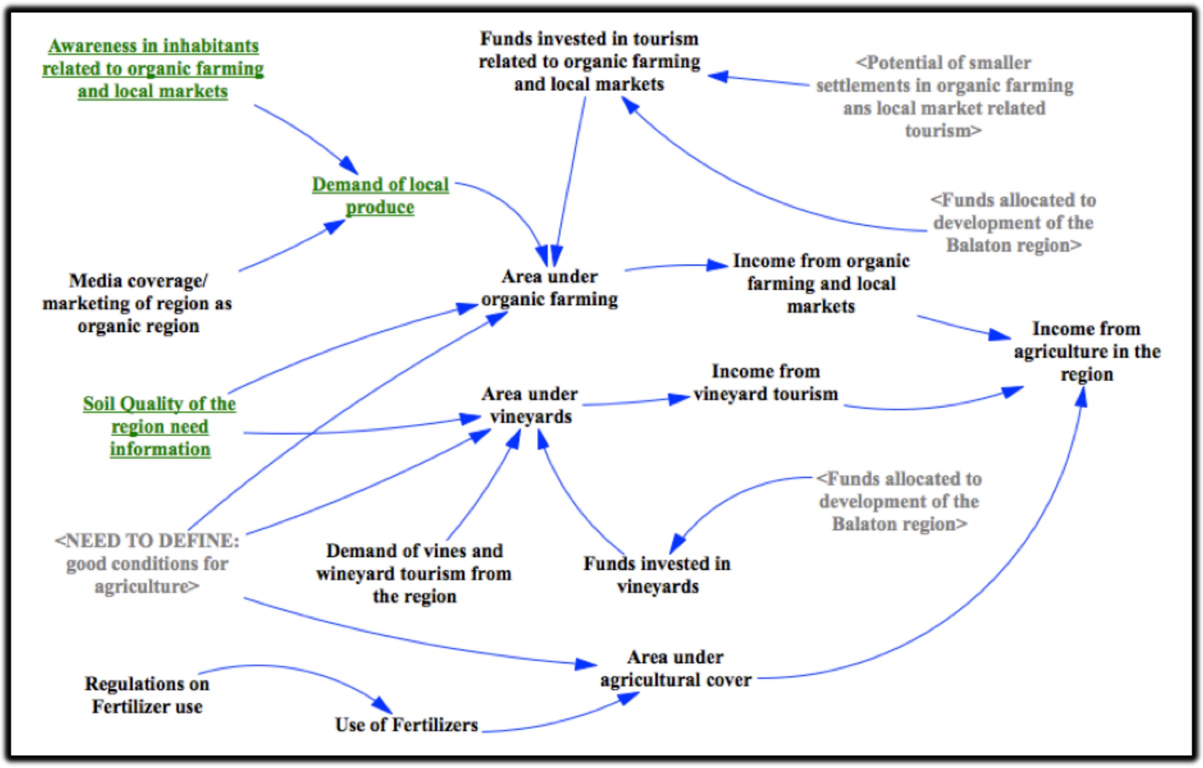

Figure 5.15: Agriculture Sector and Economics

The need to increase awareness in the inhabitants about the benefits of local organic food and the increasing the demand for local products were mentioned as points of intervention during the PSD sessions. There are connections to and from the economic subsystem through income from agriculture and funds allocated to different types of agriculture related developments programs in the region

5.8.5 Other Economic Factors in the Region

Health infrastructure is also an important component, although it did not feature prominently during the PSD sessions. There are three important features of the health infrastructure: availability, quality, and accessibility. The accessibility feature is heavily dependent on the public transport infrastructure. The increasing number of elderly inhabitants in the region, a variable observed in the demography layer, leads to increased demand for better health infrastructure. The region also has a high potential for health and wellness tourism due to the pleasant climate and thermal lakes. This infrastructure subsystem has connections to the economic sub-system through funds and addition to the income of the region. There can be intervention points around the demand and the potential of the region for health and wellness tourism.

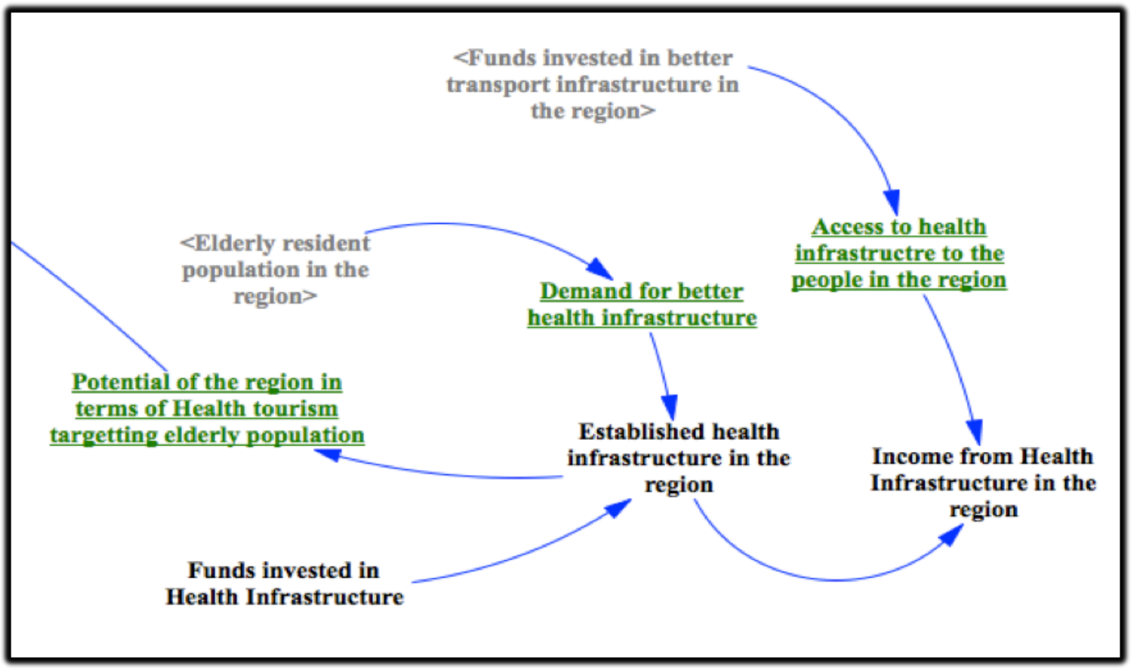

Figure 5.16: Health Infrastructure and Economics

The layer also depicts the transport infrastructure in connection with the different sectors. Both, 'improvement in roads for private transport' and 'improvement in the quality and frequency of the public transport' were suggested as interventions during the PSD sessions. Both these avenues are closely connected with the funds allocated to the transport infrastructure. These improvements will not only aid tourism in smaller settlements, especially those that are away from the shoreline, but also aid the health infrastructure and, thus, the overall wellbeing of the region.During the PSD sessions, the following two interventions were suggested for improving dynamics at this layer: (a) removing the fragmented representation in the Parliament having a united Balaton county, (b) ensuring political empowerment at the local level, in order to facilitate local level decision-making.

5.9 Findings and Analysis of Layer 7: Tourism Perceptions

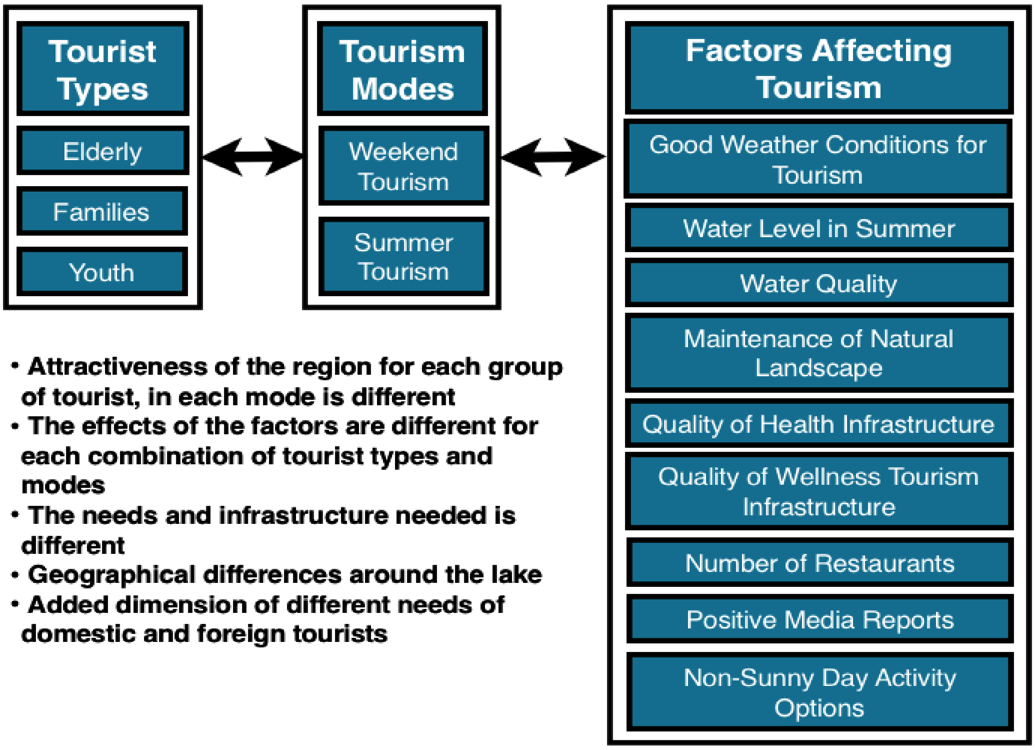

Figure 5.17:Meta-Model of the Tourism and Perceptions Layer

Tourism is one of the most crucial elements of the system. Not only is it the highest income-generating sector of the region, but it also has significant effects on other issues in the region. Tourism is a very complex sub-system in the region that is significantly driven by the perceptions of stakeholders and other actors. As mentioned before, the economic, political, and infrastructure related aspects of tourism were covered in the earlier section. This layer addresses only the attractiveness aspect of tourism and the direct influence of this attractiveness on the income of the region through tourism. This sub-section introduces the structure of this complex layer.

The structure of the layer can be seen as composed of the three elements: (a) Types of Tourists, (b) Modes of Tourism, and (c) Factors Affecting Tourism. The complexity of the tourism issue, as a whole, has many dimensions. There are three types of tourists: (i) Elderly Tourists, (ii) Families with Children and, (iii) Youth. There are two modes of tourism: (a)

Weekend Tourism and (b) Summer Tourism. The needs of the three different types of tourists for the two different modes of tourism are substantially different. Thus, the needs for infrastructure also vary accordingly. To add to the complexity, in all, nine factors were identified in the PSD sessions that have a significant effect on 'attractiveness of the region for tourists'. These factors are: (i) Good Weather Conditions for Tourism, (ii) Water Level in the Summer, (iii) Water Quality, (iv) Maintenance of Natural Landscape, (v) Quality of Health Infrastructure, (vi) Quality of Wellness Tourism Infrastructure, (vii) Number of Restaurants, (viii) Positive Media Reports, and (ix) Non-Sunny Day Activities. These factors affect the three kinds of tourist differently for each of the two kinds of modes of tourism. Thus, these nine factors vary for each the six combinations of the type of tourists and modes of tourisms. It needs to be mentioned here that there are some additional factors affecting tourism (other than the nine mentioned above) that were mentioned in only one of the PSD sessions. These include: 'frequency of public transport to the region' and 'distances from major cities as factors.' Though they are not included in the list of nine factors, they are included in the simplified causal diagram.

There exists an added dimension of the needs of the foreign tourists being different from the domestic tourists. There also are geographical differences in the locations around the lake, which adds to the complexity.

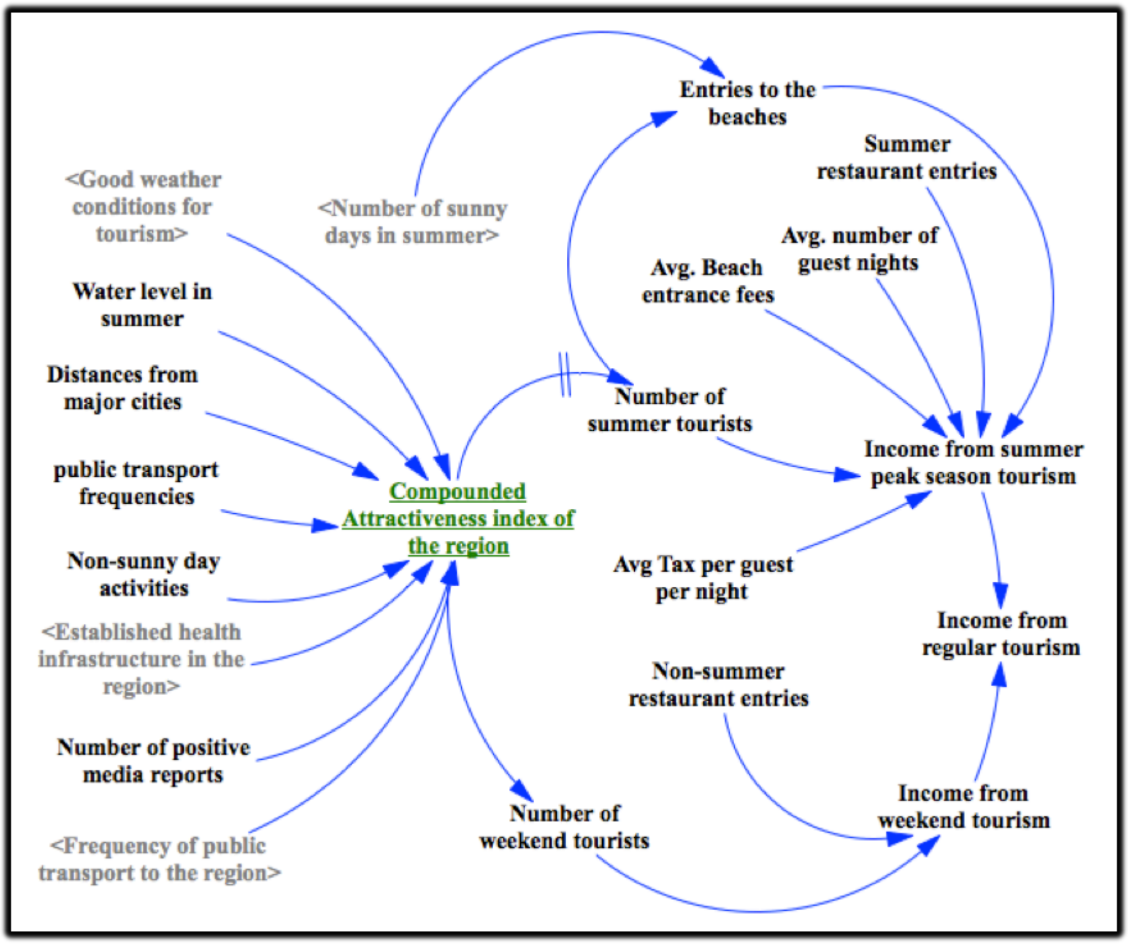

Figure 5.18 Simplified CLD of the Tourism and Perceptions Layer

Ideally, the model would benefit from defining how these different factors affect the different kinds of tourist for the different modes of tourism. But it is a difficult task and would require extensive surveys combined with statistical and behavioral analysis. Considering the limitations on the exercise to develop this pilot-level model, the complex dynamics is simplified, in order to facilitate the modeling process and understanding of the impacts of tourism. One way to simplify the complexity is to define an aggregate variable, which could be called 'Compounded Attractiveness of the Region for Tourists' of all the three types and for both the modes of tourism for each of these types of tourists. This could be defined in terms of the weighted index of the nine factors for six combinations of the type of tourists and modes of tourism. This will require extensive surveys to generate primary data, however, it will not be as complicated as creating different attractiveness indices for the different combinations of tourism types and modes.

The attractiveness of the region affects the number of summer tourists and weekend tourists in different manners. The summer tourists make decisions and bookings well in advance; and they base their decisions on the conditions of the region during previous years. Thus, there is a delay in the manifestation of the effect of attractiveness of the region for summer tourists. Though the number of summer tourists is based on attractiveness of the pervious years, the weather conditions during the same summer season affects the entries to the beaches in that season. This layer has feedbacks from the Water level, water quality and the politics, economics and conflicts level and has feed back to the Income from tourism in the 'politics, economics and conflicts' level. This layer also needs more work in terms of understanding and representing the different perceptions related to tourism, as the suggested interventions will also change based on the target tourist kind and mode. The following interventions were suggested during the PSD session to improve the dynamics at this level: (a) increasing tourist activities on non-sunny days, (b) enhancing other facilities that would widen the attractiveness of the region for tourism. These other facilities would include: health facilities (for health tourism), conference facilities (for conference tourism), and heritage sites and local markets (for heritage tourisms).

5.10 Findings and Analysis of Layer 8: Shoreline Development

This is a very simple layer that is closely connected with the Biodiversity layer. It also provides space for possible interventions for increasing the water storage (and hence water level) in the lake. The central problem in this layer is of the conflict between human needs and environmental needs pertaining to the shoreline of the lake. Facilitating human activities require the construction of concrete embankments along the shoreline for protection from flooding and for ensuring public access to the lake as per the concerned regulations. As against this, the environmental needs pertaining to the shoreline require the maintenance of the natural shoreline for the protection of reed beds. The other factors of concern in this regard include monitoring of harmful human activities such as: (a) illegal construction along the shoreline and (b) over-use of fertilizers for development of grass cover along the shoreline.

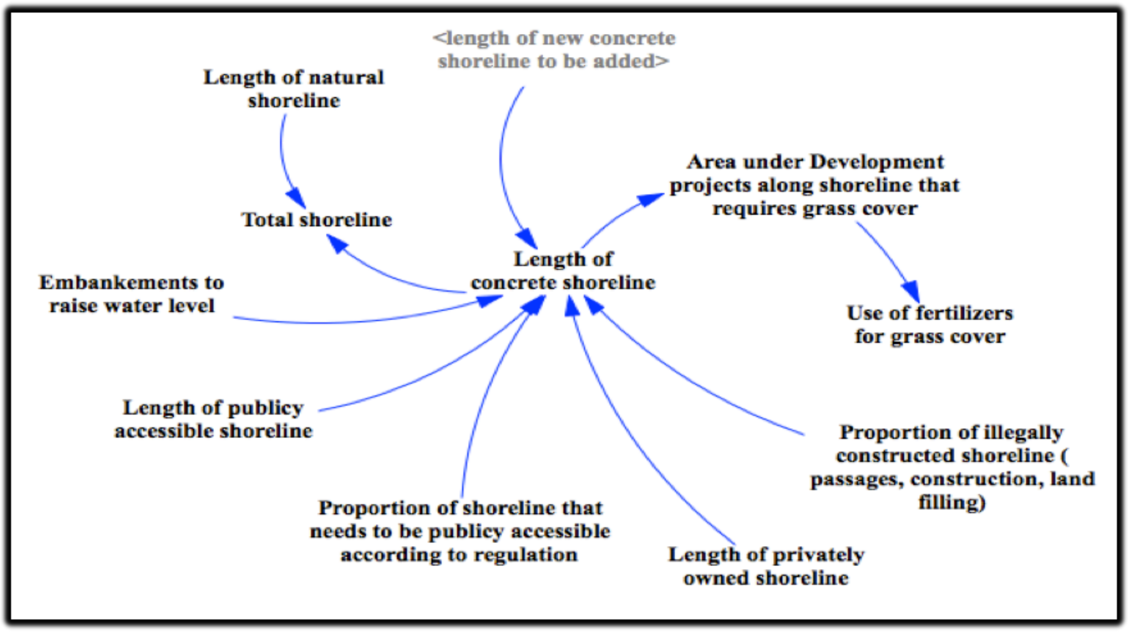

Figure 5.19:Shoreline Development Layer

Chapter 6: Conclusion: Taking a 'Step-Back' View

Taking a step back, the discussion in this chapter views the entire research effort for the thesis through a contemplative lens. To mark the conclusion of this report on the research, it presents few remarks on achievements and limitations of the research as well as some ideas about its utility in terms of possible future work based on it. The chapter contains three sections. The first section presents a brief summary of what was achieved in the effort to respond to the two research questions. The second section looks at what could not be achieved, by summarizing the lacunas in response to the first research question as well as gaps that were identified in the pilot-level model developed. In the third section, the work that can be possibly undertaken in the future is discussed. This work in the future is envisaged in two directions: (a) quantifying, simulating, and further enhancing the pilot-level system dynamics model, and (b) developing an interactive multi-purpose tool, using the model. The interactive tool could be used by various stakeholders, experts, citizens, and decision-makers for communicating, awareness-building, negotiations, consensus-building and finally for decision-making.

6.1 What Was Achieved during the Research Effort?

The research was focused on the two research questions, which essentially required development of a system dynamics model through two stages. This section—describing what was achieved in pursuit the answers the two research questions—is organized in two subsections each of which is devoted to discussion on achievements pertaining to one research question.

6.1.1 Achievements Pertaining to the First Research Question

The first research question required development of a conceptual system dynamics model using inputs from previous research conducted on the Balaton region, using the tools of Scenario Planning(SP) and Indicator Systems (IS). This model was to be used as the base for understanding the Balaton SES. For responding to this research question, first, a methodological procedure was needed that would help the researcher to develop a system dynamics (SD) model, using the inputs from the knowledge base created through previous research on the Balaton region. The knowledge base would include the data collected, conceptual frameworks developed, analysis carried out, and findings evolved during the previous research efforts. This previous research on the Balaton region was conducted using the two research tools, viz., Scenario Planning (SP) and Indicator System (IS). The required methodological procedure was developed using the understanding and insights gained through the thorough review and analysis of the literature on the three tools involved, i.e., SP, IS, and SD. Using this procedure, a systems dynamics model of the SES of the Balaton watershed region was developed.

It is called as the base model, as it is just a preliminary version, but also because it is to be used as the foundation for developing a more detailed and expanded version of the model, in response to the second research question. It needs to be noted that this methodological procedure can be used in other similar situation, possibly with some adaptations.

6.1.2 Achievements Pertaining to the Second Research Question

The second research question required the researcher to develop a pilot-level conceptual system dynamics model of the Balaton SES' using inputs from sessions with representatives of stakeholders based on the Participatory System Dynamics methods.

Responding to this research question required articulation of the methodological procedure for using the PSD method. Again, such a procedure was developed using the understanding and insights gained through the detailed review and analysis of the literature on various methods and tools used for system dynamics model. The required procedure was developed by drawing and adapting different elements from the two methods, viz., Group

Model Building (GMB) and Community-Driven System Dynamics (CDSD).

This was one of the major achievements of this research. This process involves three major stages, in which PSD sessions—individual or group—would be conducted with different objectives that are appropriate for different stages of development of the system dynamics model. When this procedure was actually deployed in the PSD sessions with the respondents in this research, it had to be further adapted to suit the ground conditions and needs of the respondents from the Balaton region.

This procedure was used for building the pilot-level version of the conceptual model of the SES of the Balaton region, comprising primarily of causal loop diagrams and stock and flow structures. Due to the limitations on time, expertise, and resources available for this research for a master's thesis, it was not possible to quantify the variables, and simulate the model in given limitations.

This pilot-level model is made of two main components. The first component is the meta-model, comprising of eight layers representing eight different themes. This complex structure was required to capture the complex and comprehensive reality of the SES of the Balaton region, comprising a multitude of intertwining interrelationships among various actors and spheres such as ecology, economy, society, and politics. The second component of the model contains conceptual system dynamics models on each of these eight layers. Each of these layers, thus, contains variables, causal links, causal loops, and, in some cases, also the feedback loops, stock and flow structures, and the inter-layer casual linkages. In addition, some suggestions were elicited from respondents on possible interventions to address the problems created by the feedback loops.

Thus, to summarize, the following are the major achievements of this research effort:

(a) The methodological procedure for developing a system dynamics model, using the knowledge base created through the previous research using the tools of

Scenario Planning and Indicator Systems

(b) The Methodological procedure for conducting sessions using the Participatory System Dynamics modeling method

(c) A preliminary, base-level model of the Balaton SES using the secondary data from previous research

(d) A complex, detailed conceptual system dynamics model—comprising eight layers—of the social-ecological system of the Balaton watershed region.

6.2 Lacunas and Gaps Remaining

6.2.1. Lacunas in the Response to the First Research Question

As mentioned before, for responding to the first research question, a methodological procedure was developed for drawing inputs from previous research efforts for developing a system dynamics model. The idea to evolve such a methodological purpose was based on the impression or assumption that, in case of many watershed or lake regions, significant volume of research has already been conducted that would provide a rich knowledge base. The methodological procedure then was developed on the basis of the review and analysis of the literature on the two research tools that had been used to study the Balaton region.

However, while using the methodological procedure in the Balaton region, three serious barriers were encountered. First, the literature on these previous research efforts in the English language that could be obtained was very limited. Second, the documentation in this available literature found to be presenting the findings and analysis of the research in a very brief manner. These two barriers severely restricted the availability of the overall knowledge base for drawing inputs for using the mythological procedure. Third, the available documentation on previous research did not provide any procedural details such as the procedural steps taken, the underlying conceptual framework. This made it difficult to apply the procedure, which was developed on the basis of literature and assumed that all these details are available.

Further, due to limitations on time resource available for this research, in the very beginning of the research effort, it was decided that the process of model building would be restricted to the development of a conceptual model. As a result, even the methodological procedure was kept restricted to the stage of conceptual model comprising causal loop diagrams (CLDs) and stock and flow structures, without getting into the stages of quantification and simulation.

6.2.2 Gaps in the Pilot-level Model

As observed during the discussion on various elements of the model of the Balaton SES in the last chapter, there are a few gaps in the structure of the model. Some important gaps are briefly listed in a summary form in this section.

- There is a need to verify some variables that emerged during the process of structuring the model, in order to remove ambiguities in the related processes.
- There is a need to verify some links that emerged during the process of constructing the model, in order to ascertain the veracity or accuracy of the modeler's understanding of the inputs obtained from the respondents during the PSD sessions. It will also help remove ambiguities in the structure of the system and better understand behavior of the system.
- Some variables mentioned by the respondents during the PSD sessions are either ambiguous or very broad. These need to be defined. In order to define them and facilitate collection of data for them, some of these variables might also require additional efforts for surveys and creation of indices.
- Many variables in the model structure are qualitative or 'unquantifiable'. For simulation of the model, these variables need to be either made quantifiable, or

substituted by appropriate quantifiable proxy variables. This would require detailed discussions with the representatives of stakeholders and experts.

- It is possible that a few important aspects or elements of the system are not covered in this pilot-level model. This would require further expansion of the model, possibly by the addition of some more layers to the model. Additional PSD sessions with different stakeholders and experts might help the identification and addition of these remaining aspects. One such aspect identified is the aspect of 'Administrative Fragmentation'. There are three counties around the lake, which have three different governance institutions of their own. In addition, three different Authorities—which are part of the national-level governance structure—governing Environment and Water sectors are also involved in governing different parts of the lake. The administrative boundaries of all these authorities are different and overlapping. All of these authorities are actively involved in decision-making pertaining to water management and corresponding issues that have impacts and implications for the ecology and community in the water of the lake. There is a need to obtain more information and, thus, better understand the interconnections and dynamics between these different political and administrative actors, and their effect on the ecological, social, and economic spheres of the Balaton SES.
- There is a need to obtain more suggestions about the required interventions in the SES. These interventions would then have to be modeled and added to the pilot model. More PSD sessions can help, not only in identifying but also understanding the causal linkages and structure of the suggested interventions and their effects.

6.3 Possible Future Steps

As mentioned before, the thesis is focused on creating the pilot-level model of the SES of the Balaton region. It is possible to make use of this pilot-level model as the foundation for future work in two directions. One direction in which the future work can proceed is to further develop this pilot-level model into a full-fledged, simulated, and tested model. The second possible trajectory for the future work is to develop a multi-purpose interactive tool—based on this model—for communication, decision-making, and negotiations. The following two sub-sections briefly describe the future work in these two directions. It needs to be noted that these two possible directions of the future work are not mutually exclusive, and involve some common steps.

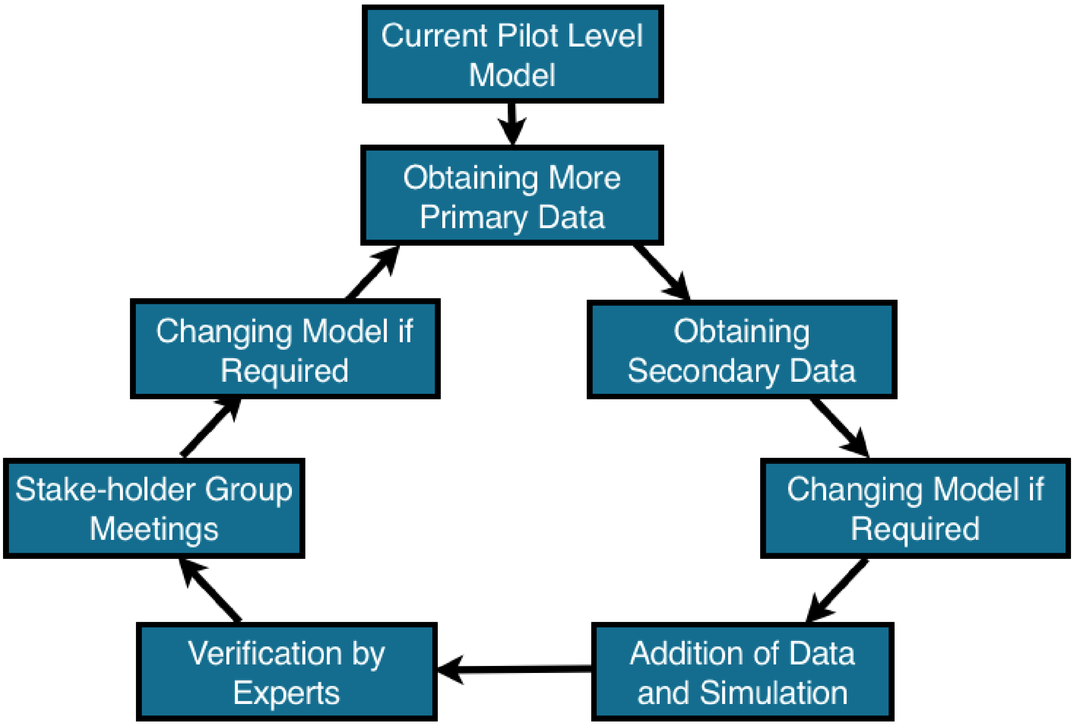

Figure 6.1: Process for Simulating and Enhancing the Model

6.3.1. Simulating and Updating the Model

This subsection presents the steps in which the future work can proceed for further developing the current model into a full-fledged, simulated model (please see Figure 6.1).

- As described before in the discussion over the gaps in the model, there are a few variables, links, and indices that need to be defined and verified. This will require the collection of additional primary data through surveys and PSD sessions in order to obtain inputs and data about these variables, links, and indices.
- If the primary data is found to be inadequate for the purpose, secondary data will have to be requested and collected from various experts, authorities, organizations, and other data sources.
- Based on the availability of the data, the model structure might have to be revised and tinkered. Proxy variables for which data can be obtained will have to be used, if needed.
- Once the model structure and data are in place, equations and data will have to be added to the model.
- The model could then be simulated and checked for problems in simulation.
- The model then will have to be verified by experts to check if it shows the observed behavior.
- This simulated and tested model can be then taken to the stakeholders to assess the utility of the model for different purposes including decision-making. It might be beneficial to convert the model into an interactive, communicative tool before this step. The idea of this tool is described in the next sub-section.
- At this stage the model might have to be revised in view of the inputs received from the stakeholders and experts during the process of the verification and assessment of utility of the model. These revisions might bring up the

requirement for more data collection and revisions. In other words, the cycle, as depicted in the figure, will have to be repeated.

- This entire process will need to be iterative and flexible in order to make the model increasingly nuanced and sophisticated, so that it can represent the real-life SES in a more elaborate manner and, thus, be put to its best use.

6.3.2 Building and Using the Interactive Tool

As mentioned before, the current pilot-level model can be converted into a multi-purpose interactive tool that can be put to many different end-uses, including the communication of information with stakeholders and other actors, building awareness about the issues involved among stakeholders and common citizens, negotiations and consensus building among stakeholders, and finally for decision-making by the authorized officials. One version of the tool is schematically presented in Figure 6.2.

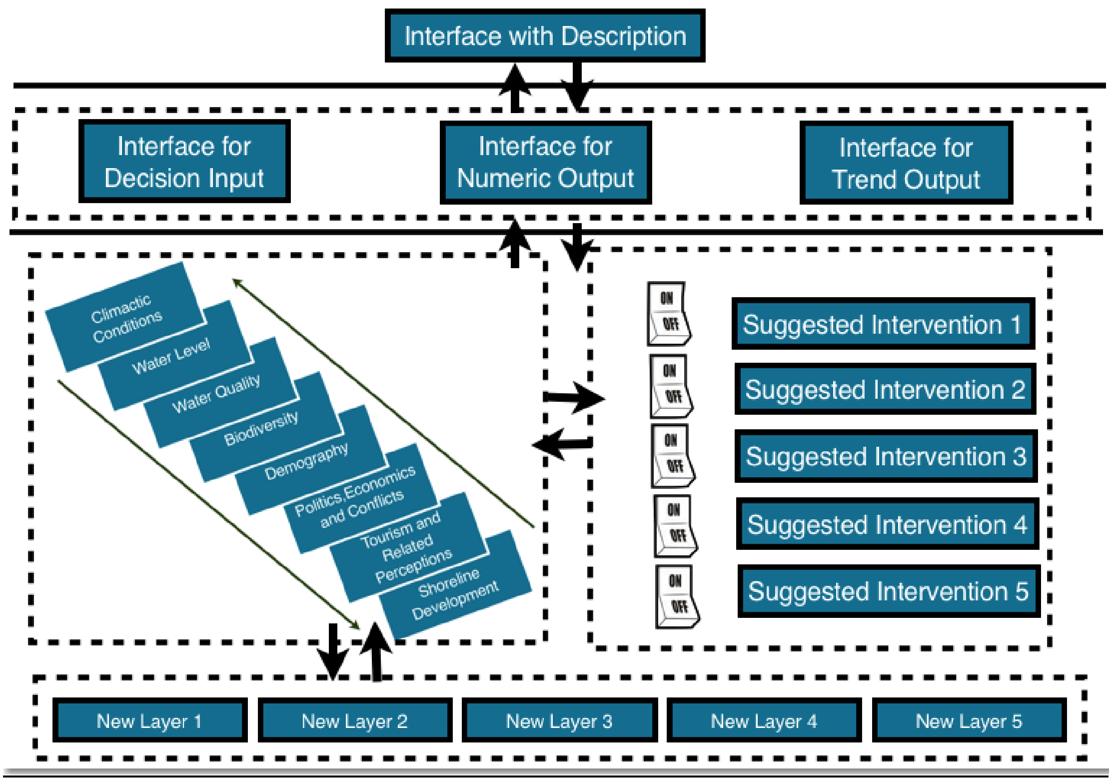

Figure 6.2: The Interactive Tool based on the Model

As depicted in Figure 6.2, the tool is envisaged to be having three levels: (i) the description level, (ii) the decision level, and (iii) the model level. These levels are briefly explained in the subsequent discussion. The process of the construction of the tool would proceed in the reverse direction, i.e., from the third to the first level.

To begin with, the third or the 'model level' of the tool is seen as having the following three sub-components: (a) the simulated and tested version of the existing pilot-level model of the SES of the Balaton region, (b) a set of suggested interventions, each with a 'switch' to 'put (the intervention) into action', and, (c) the facility to add new layers of the model in order to expand the model further. After the addition of data and equations to the three sub-components, the model level will have to be simulated and verified. This is to be followed by the testing process to ensure smooth working and correct outcomes from the simulated model placed in the 'model layer.'

The second level in the tool is the 'decision level'. This level is also envisaged to be comprised of three sub-components, or more specifically, of three interfaces: (i) interface for 'Decision Input', (ii) the interface for 'Numeric Output', (iii) the interface for 'Trend Output'.The interface for decision input will have various switches and sliders that will help the stakeholders 'personalize' their models by adding inputs necessary to create scenarios. These switches and sliders will be connected to corresponding variables, equations, and suggested interventions in the 'model level' of the tool.The 'decision inputs' provided by the stakeholders will then be used to 'run' a simulation of the model, resulting in the creation of scenarios depicting the 'alternative reality' created due to the decisions made by the user of the tool.

To view results of this simulation, the user can select one of the two interfaces: (i) Numeric Output or (ii) Trend Output. The user will be able to view these results in comparison with the business as usual (BAU) scenario built in the original simulation of the model in the tool.

The third level of the model, the 'description level,' will contain the description of the elements of the SES that are integrated in the model such as the watershed, the different spheres of the Balaton SES, the process of model building, the model structure, and different components.

In contrast to the construction process, while using the tool, the user will be using the model from the first to the third level. The user—academic or other type of user—will first be directed to the description level, where the user would be able to read information of the SES, if desired. Then the user would be directed towards the interface for the 'Trend Output,' which is located on the 'decision level'. This will allow the user to view the current trends or trends as per the 'business as usual' (BAU) scenario. If desired, the user can also explore the interface of 'Numeric Output' in order to get the quantitative picture and detailed idea of the BAU scenario.

In the next step, the user—especially the decision-maker, interested stakeholder, or expert—will be able to use the tool by accessing the interface for the 'Decision Input.' The user can create its own personalized 'alternative reality,' by entering changes using the sliders and switches and sliders provided at this level. The user can then compare result of its decisions with the 'business as usual' scenario in either of the two formats, numeric or trend. If desired, the decision-makers can access the 'model level' of the tool in order to understand the structure of the model, and even add interventions or layers in the model with help of modelers.

Appendix 1

List of Respondents

Respondent and Affiliations	Area of Expertise / Interest	Comments on the Need for Further Research?
Dr. Gábor Molnár Managing Director, Lake Balaton Development Coordination Agency	Project management, regional development, water and environmental management	Yes, there is need for further researches. But what might be also important, solution should be found to take the results of these researches into account during decision making.
Ms. Zita Egerszegi Environmental Director, Lake Balaton Development Coordination Agency	Project and environmental management, experience in water quality management and wasteland-restoration	Yes, there are many environmental aspects concerning the lake that should be further researched
Mr. Miklós Oláh Head, Social Science Research Group, Lake Balaton Development Coordination Agency	Elaboration of environmental, social and economic surveys concerning the Lake Balaton Region, experience in tourism development as well as vulnerabilities and adaption options	Yes, further research is needed especially in the open topics discussed during the interviews (difference between territorial borders, economic and social sustainability).
Ms. Éva Geletáné Varga Project Manager, Lake Balaton Development Coordination Agency	Project management, experience in tourism development, as well as vulnerabilities and adaptation options	Yes. More research is needed to better understand the lake, and to better handle the problems arising.
Ms. Gabriella Kravinszkaja Head, Water Management and Hydro-geological Monitoring Unit, Central Transdanubian Water Authority	Water management activities of the 3 counties around the lake, hydro-geological monitoring, enhancing ecological impacts, implementation of the tasks of the Water Framework Directive, controlling water quality, elaboration of development concepts and recommendations.	Yes, absolutely. Researches should be continued in the future.
Dr. Károly Kutics Managing Director,	Water quality, environment, regional development	Yes, both specialized and multi-disciplinary research is needed.

R&D Consulting and Environmental Services llc., Veszprém, Hungary Senior Researcher, Kaposvár University, Balaton Research Institute, Kaposvár		
Mr. Robert Manchin, Deputy Mayor, Vallus village, and Chairman, Gallup Europe	Sociology, Regional Development, Measurement, Social Indicators	Definitely
Prof. Anna Vari Private Professor, Budapest University of Technology and Economics, Dept. Of Environmental Management	Environmental and Water Policy, Public Participation, Conflict Management	Yes, More research needed.
Mr. Levente Huszti Nemzeti Fejlesztési Ügynökség (National Development Agency), Hungary	Rural development, local communities and governments, regional development	No. More action is needed and educated work force for implementing those strategies that are lying in drawers somewhere.
Prof. Laszlo Pinter Professor, Central European University, and Senior Fellow, International Institute of Sustainable Development	Sustainable development goals and governance; measuring genuine progress; global environment outlooks and scenario analysis; adaptation and resilience of socio-ecological systems; integrated environmental assessment	Yes, definitely, particularly policy relevant, participatory research that involves stakeholders in the analysis.
Dr. Zoltán Alföldi Associate Professor, University of Pannonia, Georgikon Faculty, Department of Plant Sciences and Biotechnology	Human Ecology, Bioethics, Environmental education and communication	Yes, definitely
Other Stakeholder Mayor of a Village in the Balaton region	Local Empowerment	

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