HKKH Partnership
for ecosystem management

Decision Suppot Toolbox

User Manual

ICIMOD & EV-K2-CNR

cesvi EvK2CNR ICIMOD IUCN

Supported by Cooperazione Italiana allo Sviluppo
Ministero degli Affari Esteri

Decision Support Toolbox User Manual

DST Development and Documentation

Sudip Pradhan, Birendra Bajracharya and Basanta Shrestha, ICIMOD

Hari Krishna Dhonju and Prashant Malla, Softwel (P.) Ltd.

Contributors

Model Development

Collaborating organisations/institutions

National: Department of National Parks and Wildlife Conservation (DNPWC), Sagarmatha National Park (SNP), Sagarmatha National Park Buffer Zone (SNPBZ) Committee, Tribhuvan University (TU), Kathmandu University (KU), Nepal Academy of Science and Technology (NAST), Sagarmatha Pollution Control Committee (SPCC), Resources Himalaya Foundation (RHF)

International: University of Naples, Italy; University of Padova, Italy; Simulistics Ltd., UK

Model development and documentation

Franco Salerno, Gaetano Viviano, Emanuela Manfredi, Robert Muetzelfeldt, Jasper Taylor, Francesco Giannino, Fabrizio Carteni, Anna Staiano, Sudip Pradhan, Sudeep Thakuri, Bastian Flury, Birendra Bajracharya, Barry Haack and Basanta Shrestha.

Thematic area contributors

Tourism sub-model:
Paolo Caroli, Daniela Panzeri of CESVI

Forestry sub-model:
Dr. Dinesh Raj Bhuju of NAST, Drs. Marco Carrer and Alessandro Tenca of University of Padova, Sanu Raja Maharjan, Sailesh Rangitkar, Narayan Gaire

Water pollution sub-model:
Prof. P. K. Jha, Mr. Bharat Babu Shrestha and Mr. Nara an Prasad Ghimire of Central Department of Botany, TU

Energy and solid waste sub model:
Prof. Ramesh Maskey, Prof. Sanjay Nath Khanal, Dr. Rijan Bhakta Kayastha, Silu Bojhyboya, Rojan Panday, Gayanedra Chaudhary and Yangji Dolma Sherpa of KU

Indoor air pollution:
Dr. Atindra Sapkota and Sandeep Shrestha of KU; Prof. Annalisa Cogo of University of Ferrara, V. Theodore Barnett, M.D, Medical College of Wisconsin

Published on behalf of the HKKH Partnership Project by
International Centre for Integrated Mountain Development
Khumaltar, Lalitpur, Nepal
GPO Box 3226, Kathmandu
Tel + 977-1-5003222
email: info@icimod.org
web: www.icimod.org

This document has been produced in the framework of the Project 'Institutional Consolidation for the Coordinated and Integrated Monitoring of Natural Resources towards Sustainable Development and Environmental Conservation in the Hindu Kush-Karakoram-Himalaya Mountain Complex' financed by the Italian Ministry of Foreign Affairs – DGCS.

Acknowledgement

The Decision Support Toolbox (DST) software has been made possible through contributions of many individuals and institutions. We would like to thank the Department of National Parks and Wildlife Conservation, Sagarmatha National Park, and Sagarmatha National Park Buffer Zone Committee for their support during the development of DST. The System Dynamics models developed for Sagarmatha National Park and Buffer Zone form integral part of the DST software. We would like to express our sincere gratitude to all the collaborators from Ev-K2-CNR, CESVI, Tribhuvan University, Kathmandu University, Nepal Academy of Science and Technology, Sagarmatha Pollution Control Committee, Resources Himalaya Foundation, University of Naples, University of Padova and Simulistics Ltd. for their contributions in the development of models which address the pertinent management issues of Sagarmatha National Park.

Table of Contents

List of Figure

List of Table

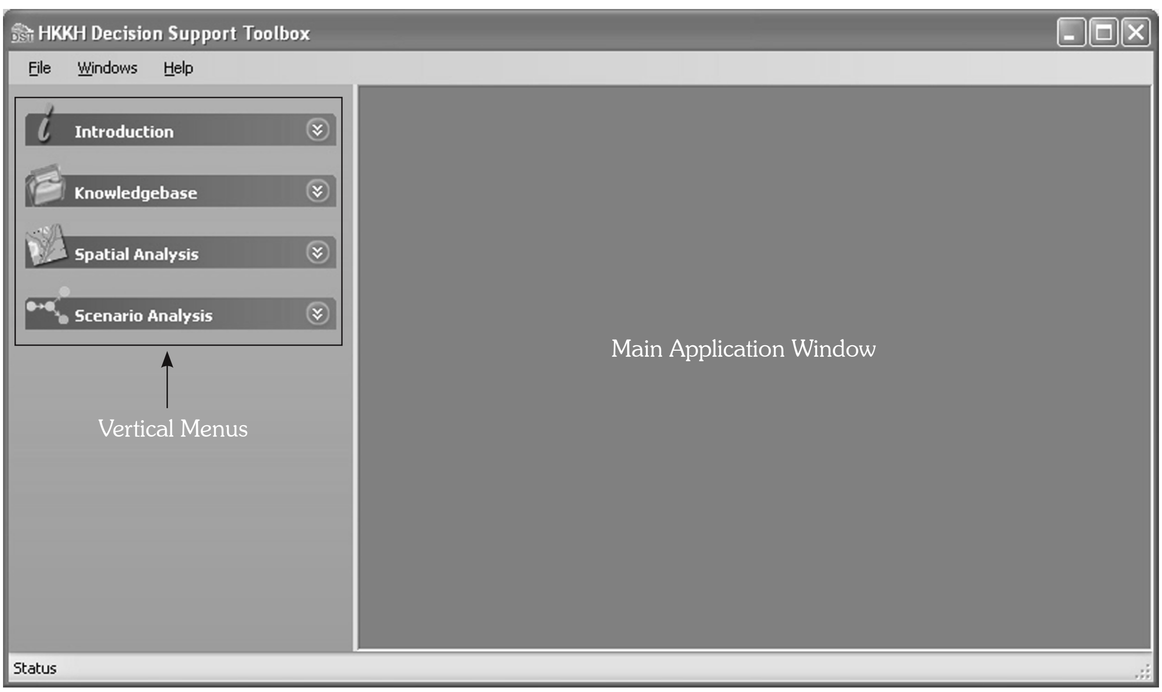
Decision Support Toolbox – An Overview

Decision Support Toolbox (DST) software has been designed and developed to provide a set of integrated but self-contained tools to support decision-making process in the ecosystem management of protected areas. The DST software contains three application modules: Knowledgebase, Spatial Analysis and Scenario Analysis.

1.1 DST Interface

The DST software consists of four vertical menus: Introduction, Knowledgebase, Spatial Analysis and Scenario Analysis. These vertical menus are collapsible in nature such that when a user clicks on a menu, it gets expanded vertically to offer users with various sub-menus.

When a user clicks menus related to application modules (e.g., Spatial Analysis), the components of DST such as menu, toolbar and main application window change accordingly providing corresponding functionalities to the users.



Introduction

As the name suggests, the Introduction menu provides basic introductory information on HKKH Partnership Project and the DST software. It provides links to various information in the form of vertical sub-menus as shown below:

HKKH Partnership Project: provides introductory information about the HKKH Partnership Project.
HKKH DST: gives a brief overview of current DST release and the available modules.
Data Packaged: provides a list of data packaged with the DST software DVD.
Third Party Software: gives a short description of third party software that may be used along with DST software.

When DST software is launched, a page with an introduction to HKKH DST is displayed on the main application window. In order to view other information, the user has to click the **Introduction** menu and click the appropriate sub-menu.

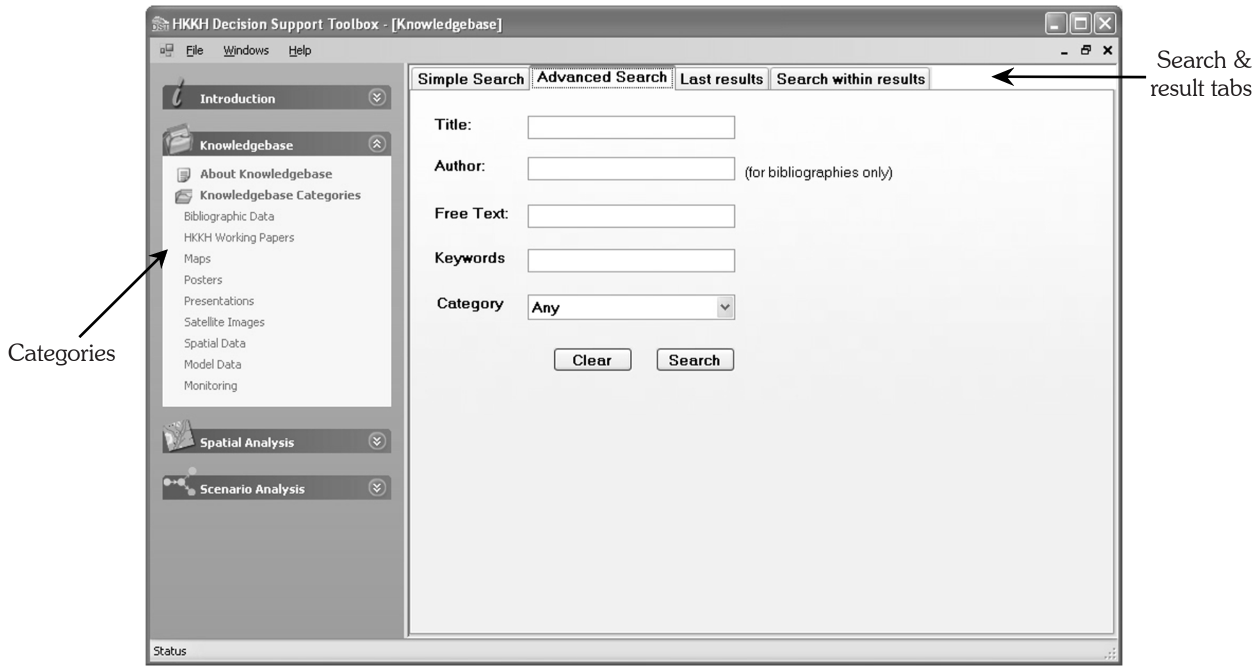
Knowledgebase

In the context of the HKKH Partnership project, Knowledgebase has been defined as the metadata management system that allows storing the metadata of various kinds of information such as literature, spatial data, satellite imageries, models and so on. This system also allows storing the data, model and other information along with the metadata.

The Knowledgebase module allows users to browse and search metadata stored in the Knowledgebase system.

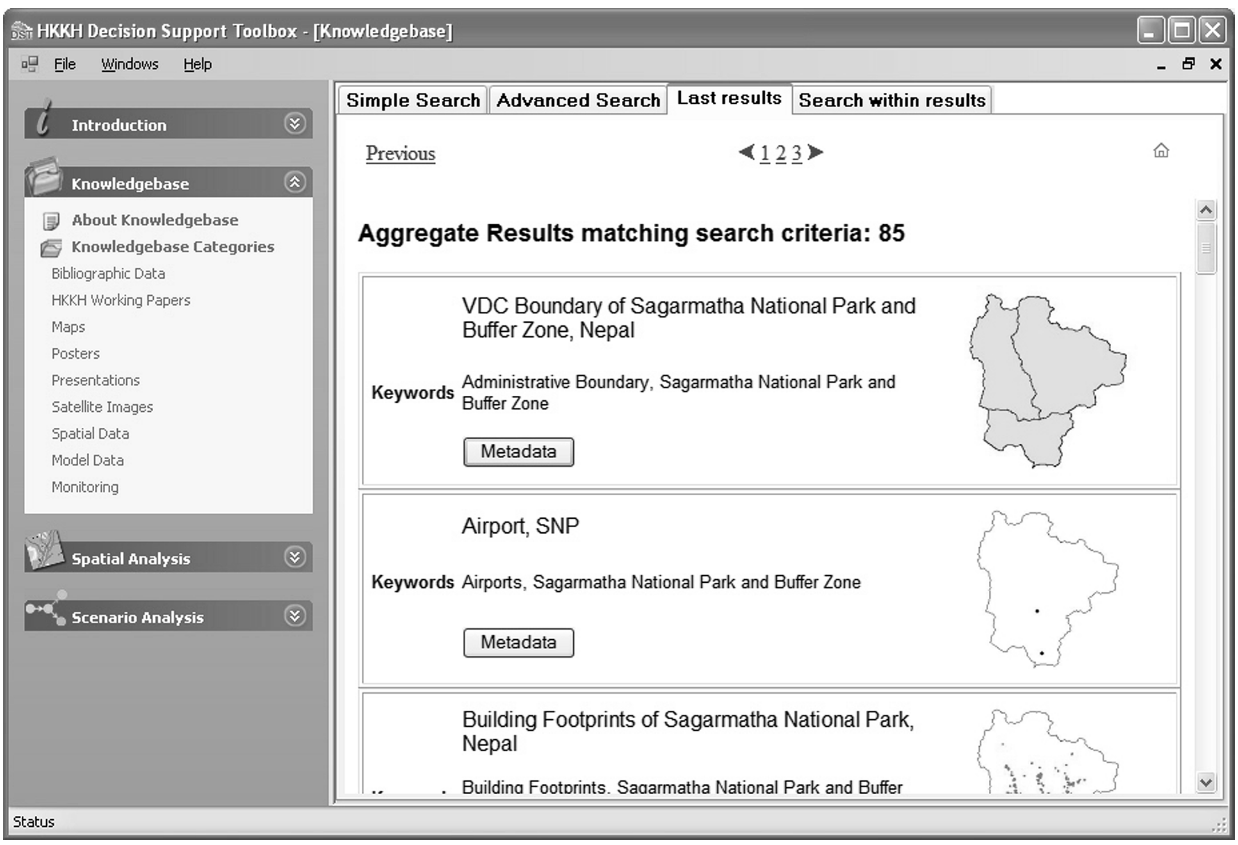
Metadata Browse

The Metadata Browse allows users to browse the metadata of various categories such as Bibliographic Data, Maps, Spatial Data, Satellite Images, etc. The categories are listed as vertical sub-menu items under Knowledgebase menu.

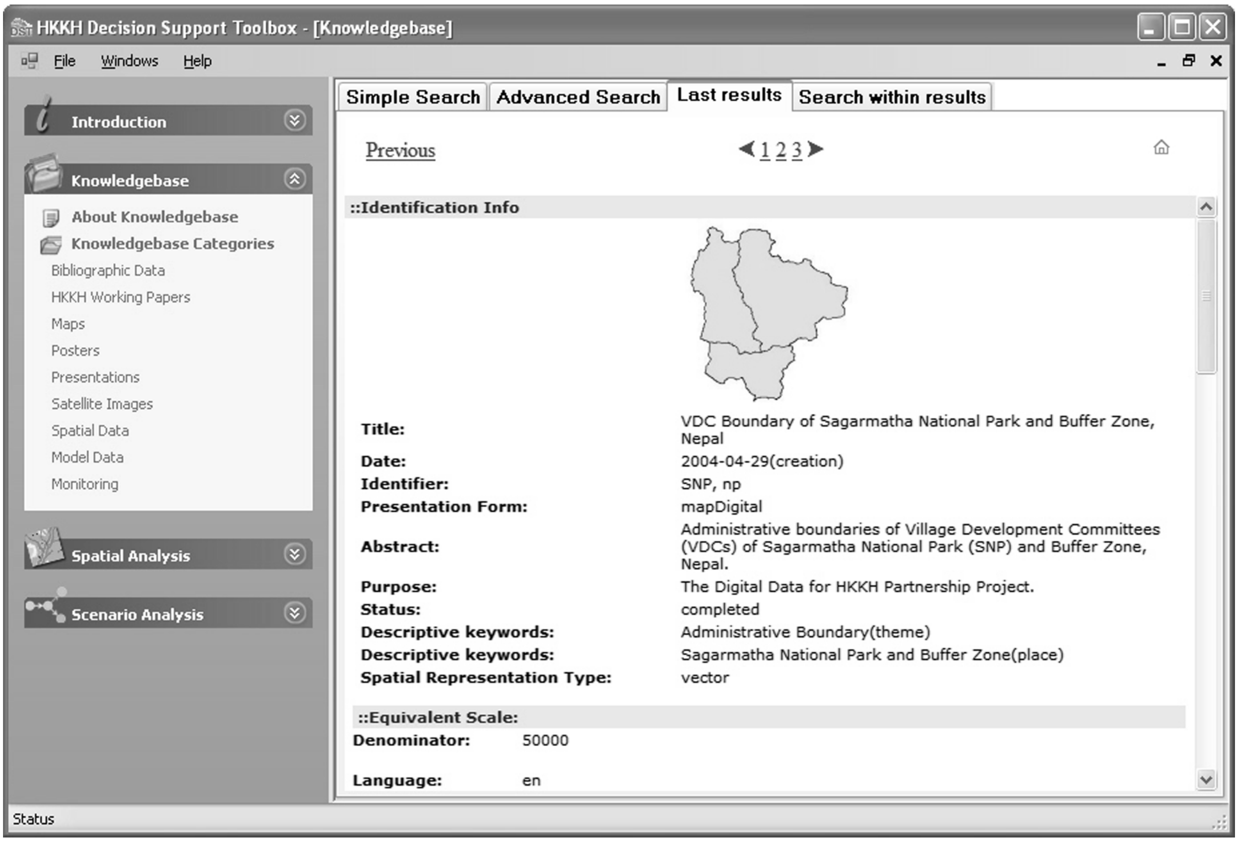


- Click **Knowledgebase** menu to launch the Knowledgebase application module. This will show introductory information about Knowledgebase in the **Last results** tab.

- Click a category sub-menu to view the list of metadata in that category. For example, clicking **Spatial Data** sub-menu will list the metadata of "Spatial Data" in the **Last results** tab as shown in the figure below:



- Click **Metadata** button to view the detailed metadata of a given spatial data.



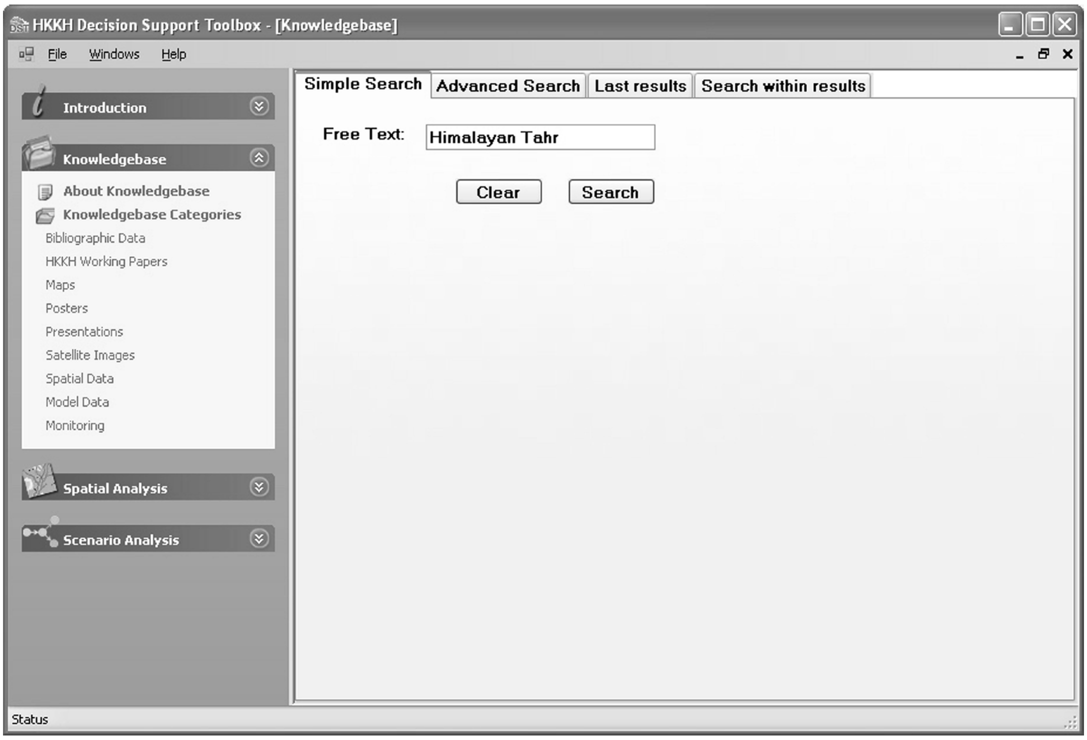
Click at **Previous** hyperlink to go back to the list of metadata.
If you want to go to the introductory page on Knowledgebase, click  image or alternatively click **About Knowledgebase** link under Knowledgebase menu.

Metadata Search

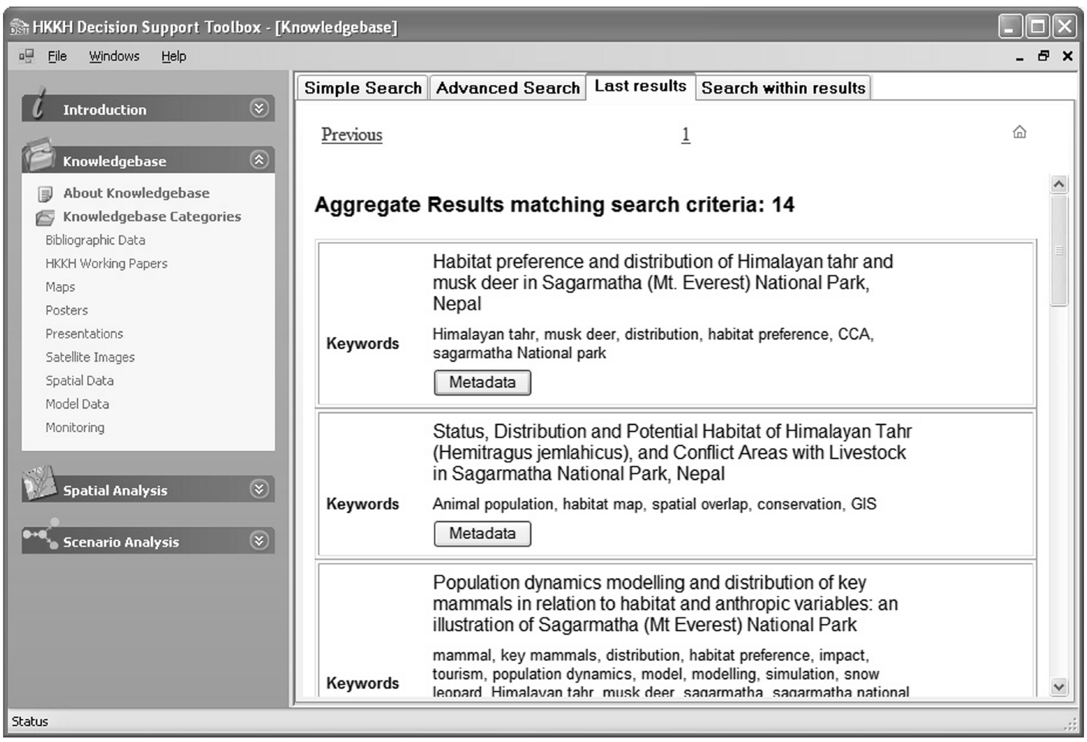
The Knowledgebase module provides three kinds of metadata search:

Simple Search: It allows users to search metadata by providing search text. It looks for the occurrence of the search text in any part of the metadata.

- Click **Simple Search** tab.
- Type search text(s) in the **Free Text** textbox provided.
- Click **Search** button to start searching.

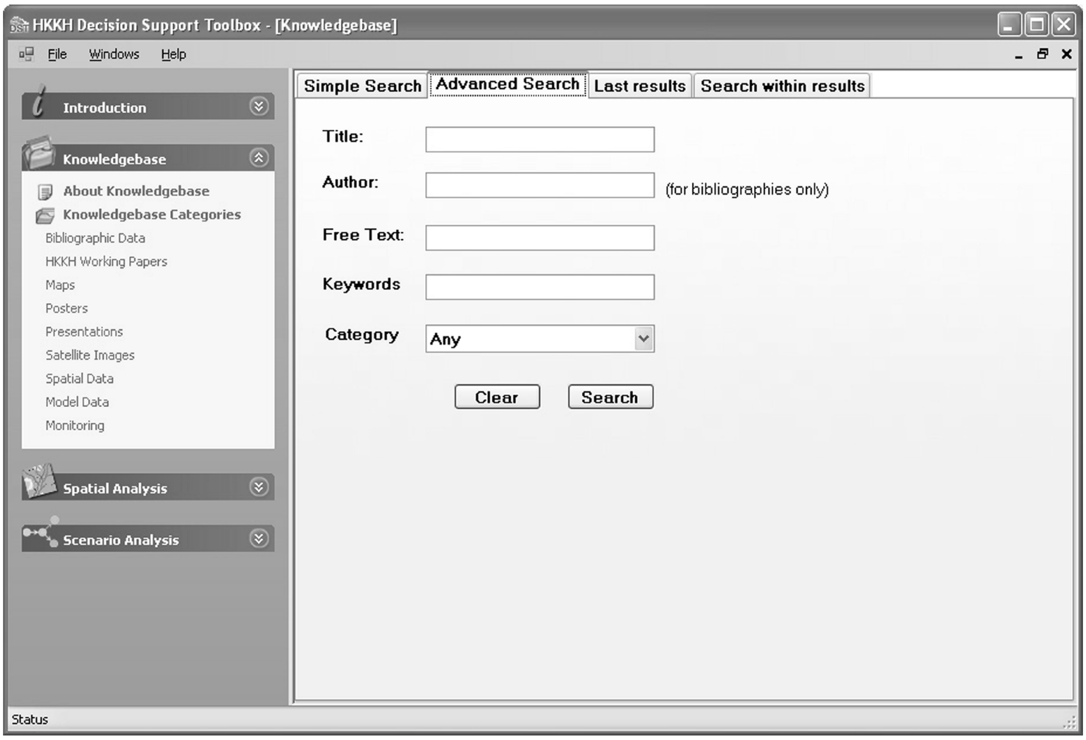


The result will be shown in the Last results tab.



Advanced Search: It allows users to search metadata more thoroughly based on title, author, keywords and free text. Furthermore, it also lets users select a category, such as "Bibliographic Data", "Spatial Data", etc. to narrow down the search within the chosen category.

- Click **Advanced Search** tab.
- Type search text(s) in the appropriate textbox(s) provided.
- Click **Search** button to start searching.



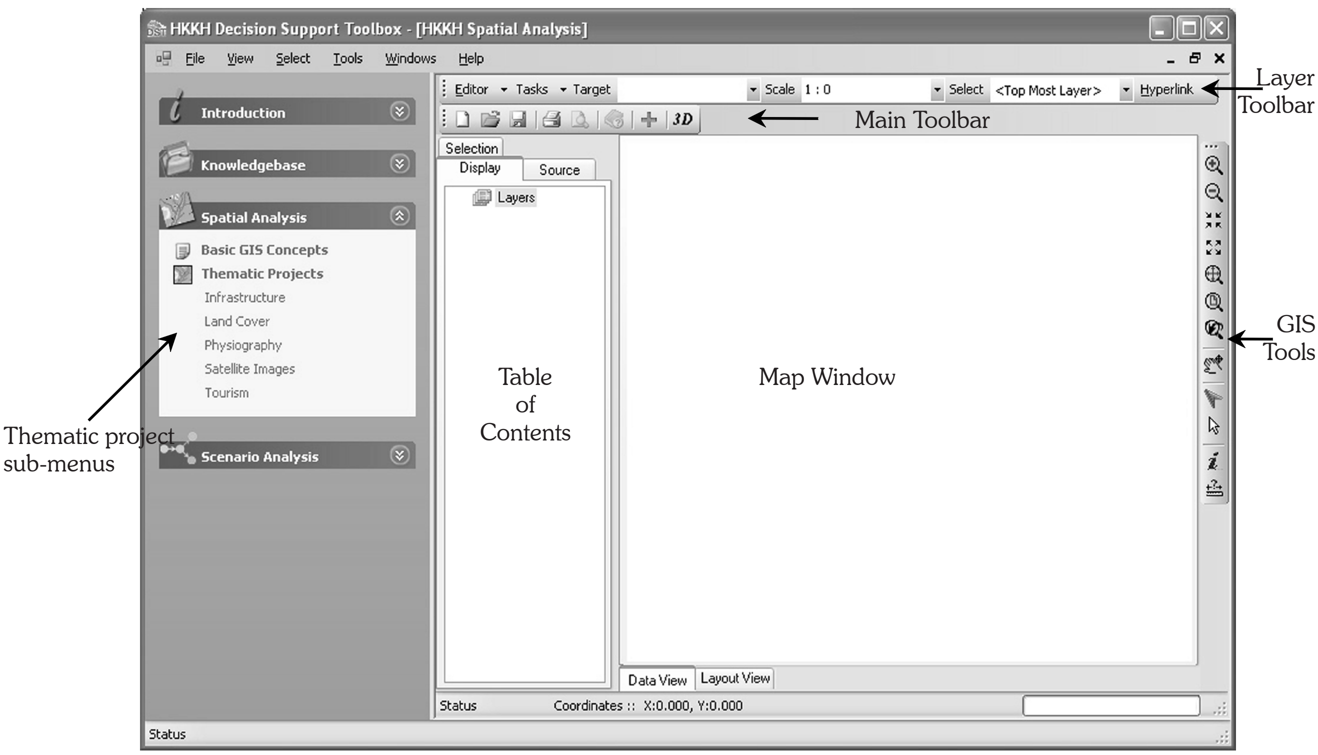
Note:

- The **Advanced Search** uses the AND logic in its search such that it shows results of only those metadata that contain all the search texts provided by the users in various textboxes in the corresponding sections of the metadata.
- The **Advanced Search** requires that the users select "Bibliographic Data" under **Category** drop-down in order to search metadata based on Author.

Search within results: It allows users to search metadata within the previous search results. This search is identical to **Simple Search** except for the fact that it searches only those metadata that have been found in the previous search result.

Spatial Analysis

The Spatial Analysis (SA) module allows users to view, create, edit and query the spatial data. The SA module consists of various components such as table of contents (ToC), Map Window, GIS Tools and Main Toolbar as shown in the figure below:



The various buttons and their functionalities in the Main Toolbar are given in the table below:

Main Toolbar

Button	Name	Functions
	New	Starts a new project
	Open	Opens the DST project
	Save	Saves the current DST project
	Print	Prints the current map
	Add Layer	Adds GIS layer to the map
	3D	Launches HKKH 3D Viewer

The various tools and their functionalities in the GIS Tools toolbar are given in the table below:

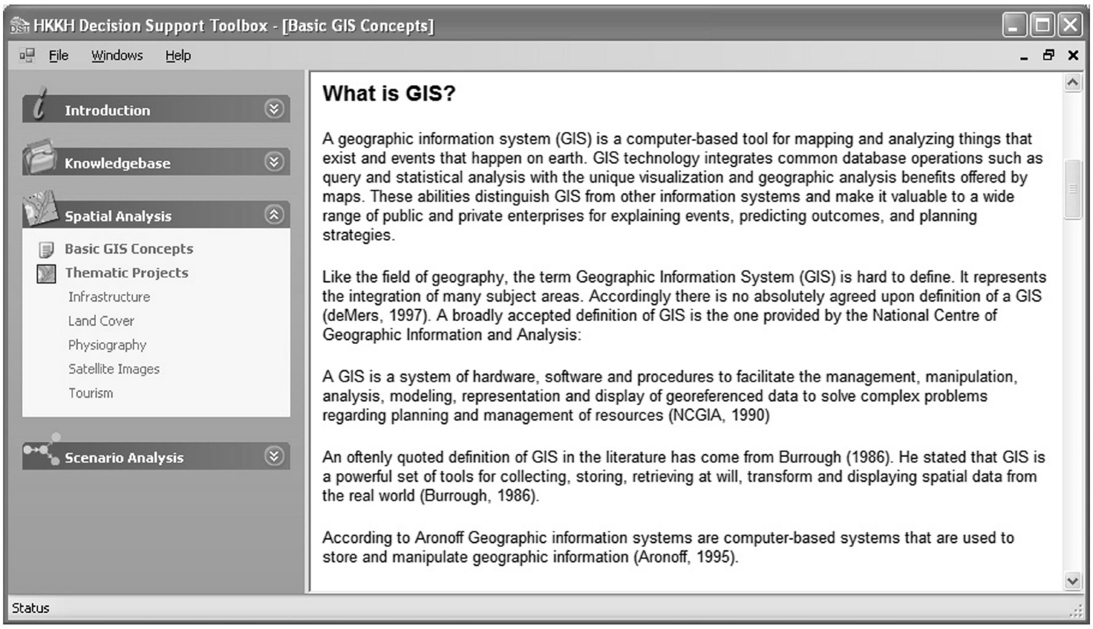
GIS Tools

Tool	Name	Functions
	Zoom In	Zooms in the map
	Zoom Out	Zooms out the map
	Fixed Zoom In	Zooms in on the centre of the map
	Fixed Zoom Out	Zooms out on the centre of the map
	Zoom Extent	Zooms to the resulting extent of all the visible layers
	Zoom All	Zooms to the resulting extent of all the layers
	Zoom Previous	Zooms to previous extent
	Pan	Lets user to pan across the map
	Selection	Selects the features on the map
	Pointer	Changes the mouse cursor to pointer
	Identify	Identifies the features that are clicked
	Ruler	Measures distance on the map

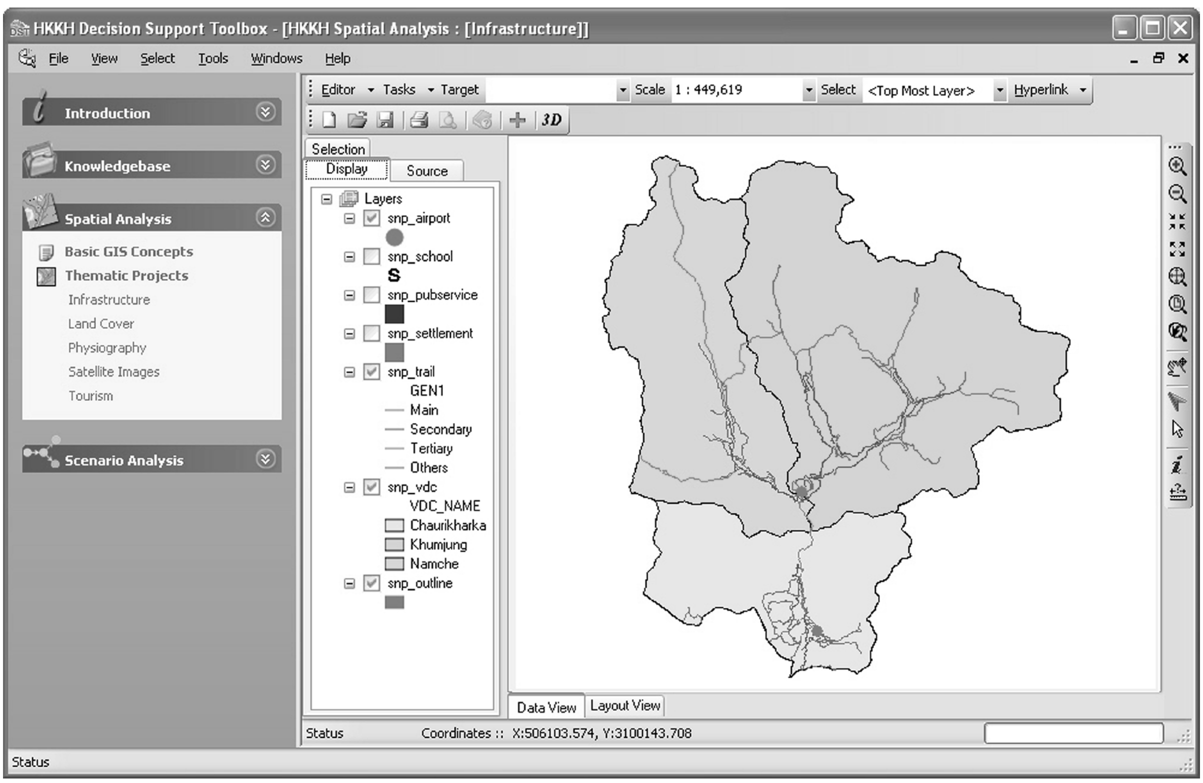
4.1 Exploring SNPBZ data

The SA allows exploring the Sagarmatha National Park and Buffer Zone (SNPBZ) spatial data packaged with the DST software. It consists of a list of thematic projects in the form of vertical sub-menus. When a user clicks a thematic sub-menu, the corresponding pre-defined DST project will be opened to show the layers in that theme.

- Click **Spatial Analysis** vertical menu in DST. The SA module will be launched showing the blank project and the **Spatial Analysis** will be expanded showing a list of thematic projects.
- If necessary, click **Basic GIS Concepts** sub-menu under **Spatial Analysis** menu. It will show a webpage containing a brief introduction to Geographic Information System (GIS).



- Click **Infrastructure** sub-menu under **Spatial Analysis** menu. The infrastructure project will be opened by SA module to show the spatial data packaged under Infrastructure thematic project.



- Turn off snp_airport layer by setting its checkbox off in the ToC. Notice that the snp_airport layer is no longer visible on the map.
- Likewise, turn on the snp_school layer in the Toc to view the locations of schools in SNP on the map.
- Use **Zoom In**  tool to zoom in any area of the map of your interest.
- Click **Zoom All**  tool to zoom the map to the full extent of all the layers in the ToC. Alternatively, click

  Zoom Extent  tool to zoom the map to the extent of all the visible layers in the ToC.
- Explore other zooming tools available in the toolbar to zoom in or zoom out the map.
- Similarly open other thematic projects using vertical sub-menus to view and explore spatial data in those projects.

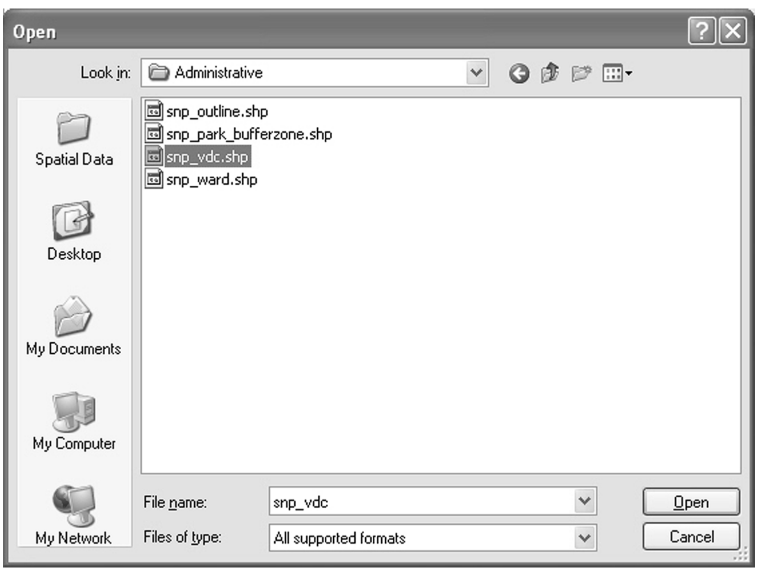
Note:

- The spatial data packaged with DST software are placed in **..\Support\Spatial Analysis\Spatial Data** folder where **..** refers to the root folder of DST installation (e.g.,*C:\Program Files\HKKH Partnership Project\HKKH DST*).

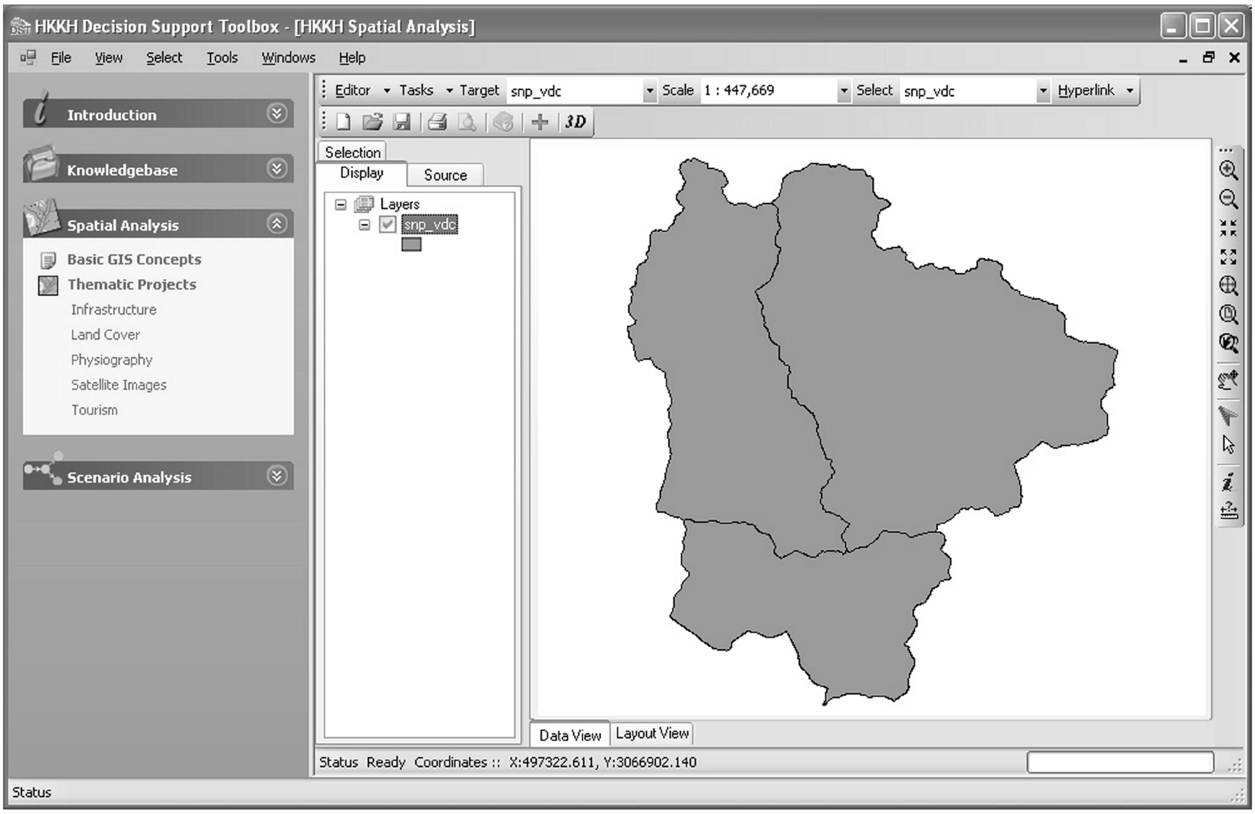
4.2 Adding-Removing spatial data layer

Adding spatial data layer

- Click **Add Layer**  button on the main toolbar. Navigate to a feature layer you want to add to the SA and click **Open**. In the **Open** dialog, click **Spatial Data** to quickly navigate to spatial data packaged with the software.



Then the *feature layer* will be added to the ToC and the corresponding map displayed in the map section of SA.



- Alternatively, click **Add Data** from the File menu and navigate to a feature layer you want to add to the SA and click **Open**
  OR
- right-click Layers and click **Add Data** in the ToC window and navigate to a feature layer you want to add to the SA and click Open.

Removing Spatial Data Layer

In the ToC, right-click the feature layer you want to remove and click **Remove**.

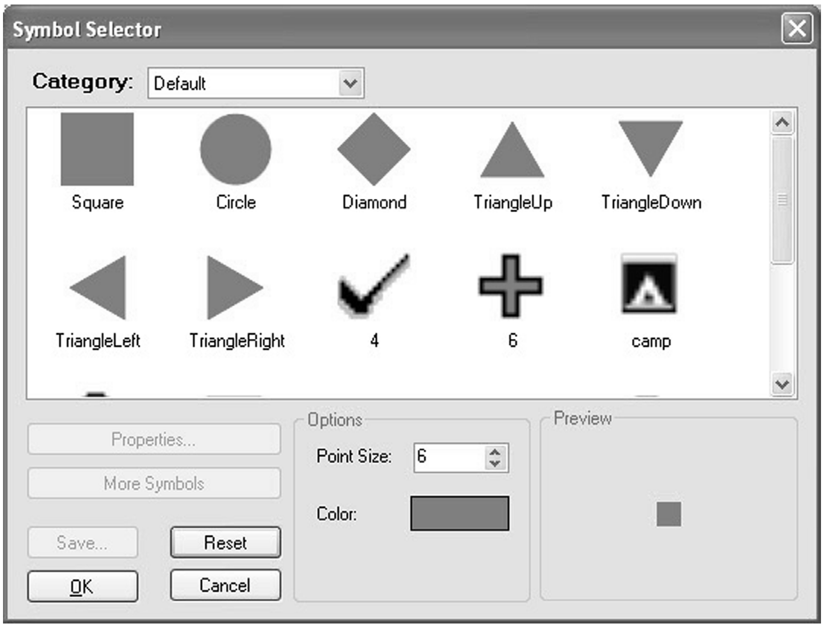
4.3 Working with symbology of feature layers

Changing symbology of a feature layer

- Add a feature layer to the map.
- In the ToC, click at the symbol of the layer.
- Alternatively, in the ToC, right-click the feature layer and click Properties. Click Symbology tab. Under Features sub-tab, click the Symbol button.
- In the Symbol Selector dialog, choose appropriate symbology for the features:

Point feature

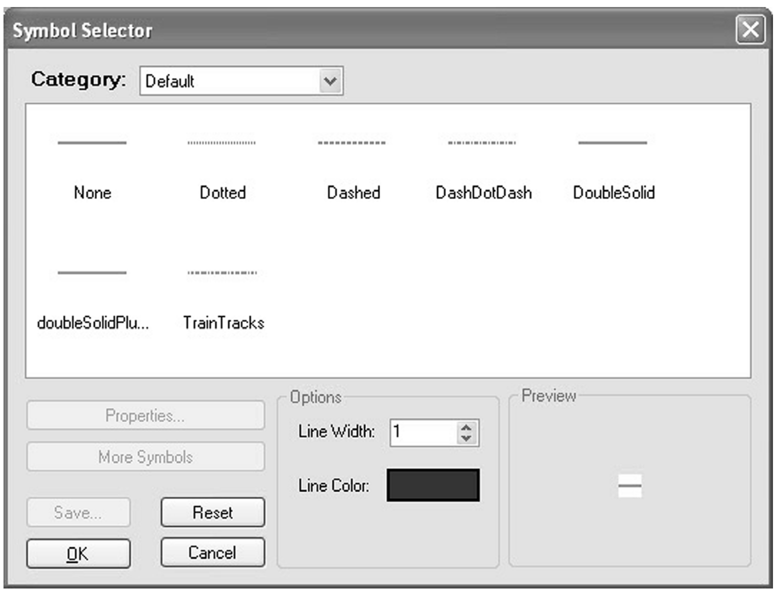
- Choose appropriate point shape from the list of available shapes (e.g., square, circle, etc.).
- Specify the color and size for the point features under **Options** group-box.
- Alternatively, choose a pre-defined symbology (e.g., camp, telephone, etc.) and specify the point size for that symbology.



- Click **OK** to apply the symbology.

Line feature

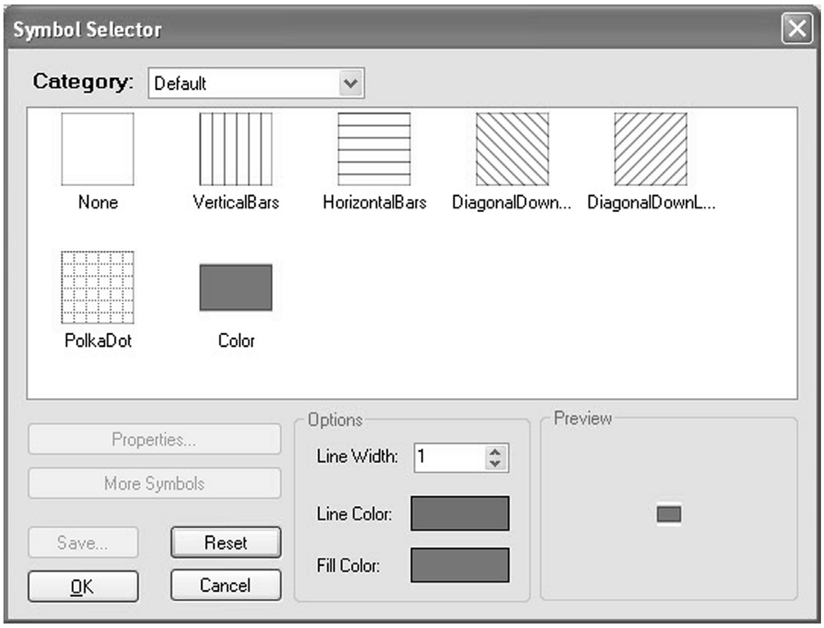
- Choose appropriate symbology for line feature (Regular or None, Dotted, Dashed, etc.)
- Specify the color and width of the line under **Options** group-box.



- Click **OK** to apply the symbology.

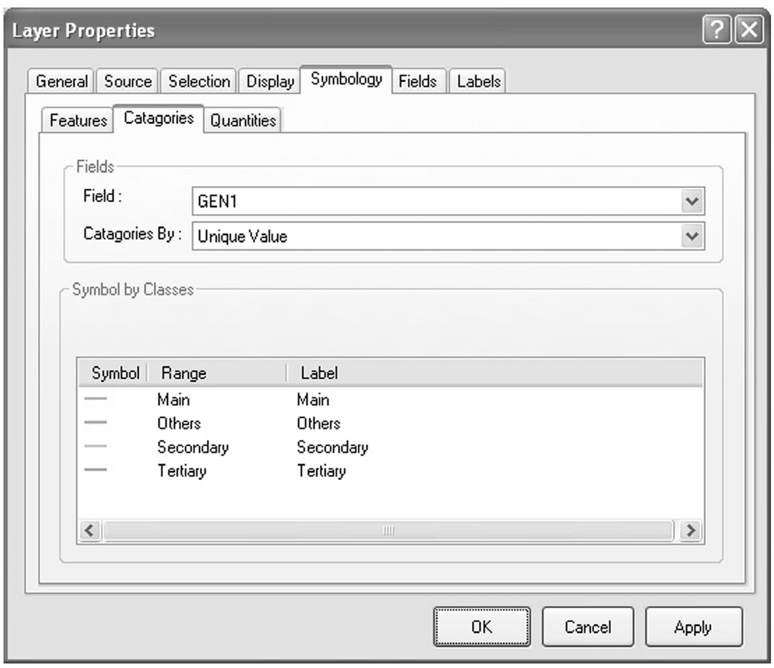
Polygon feature

- Under Options group-box, click Fill Color to set color for the polygon features.
- Next, click Line Color to set color for outline of the polygon features.



- Specify the width of the outline of polygon features under **Line Width** listbox.
- Alternatively, choose a pattern you desire to set for the polygon features.
- Choose **None** from the list of symbology types if you want to set the polygon as transparent.
- Click **OK** to apply the symbology you have chosen.

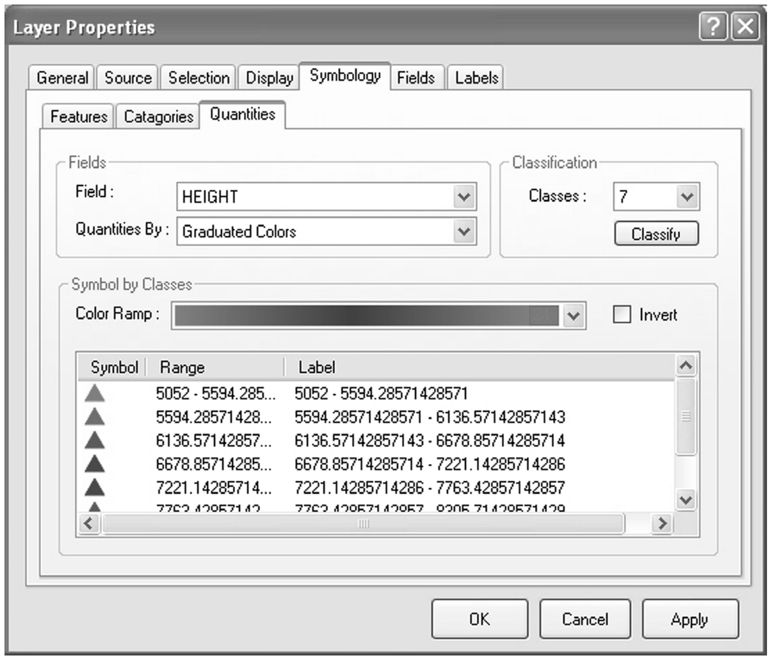
Symbolising features by categorical attributes



- Add a feature layer to the map.
- In the ToC, right-click the feature layer and click **Properties**.
- Click **Symbology** tab.
- Switch to **Categories** sub-tab.
- Click the **Field** drop-down list and select the field for classification. Leave *Unique Value* under **Categories By** drop-down.
- Click **Apply** to view the symbology applied on the map window.
- Click **OK** to close the **Layer Properties** dialog.

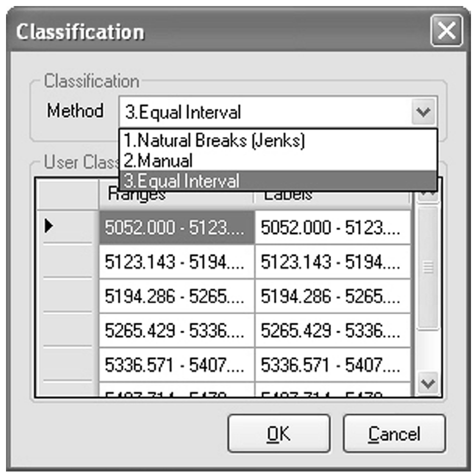
Symbolising features by quantities

- Add a feature layer to the map.
- In the ToC, right-click the feature layer and click **Properties**.
- Click **Symbology** tab.
- Switch to **Quantities** sub-tab.
- Click the **Field** drop-down list and select the appropriate field for classification.
- Click **Color Ramp** drop-down and choose a color ramp of your choice.
- Choose number of classes from the **Classes** drop-down.

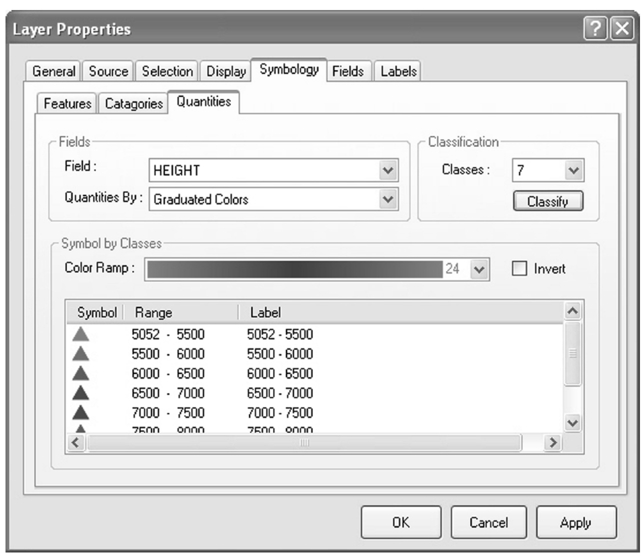


By default, the system creates classes based on Natural Breaks classification method.

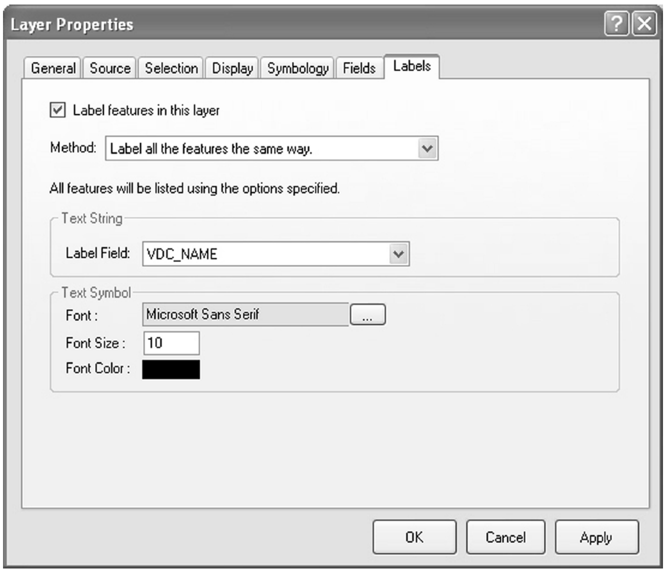
- If you want to set the classes based on Equal Interval classification method, click Classify button. This will open the Classification dialog.
- Select **Equal Interval** under **Method** drop-down and click **OK**.
- Click **Apply** to view the symbology applied to the feature layer on the map window.
- Click **OK** to close the **Layer Properties** dialog.
- If you want to set the classes based on your own classes, click **Classify** button.



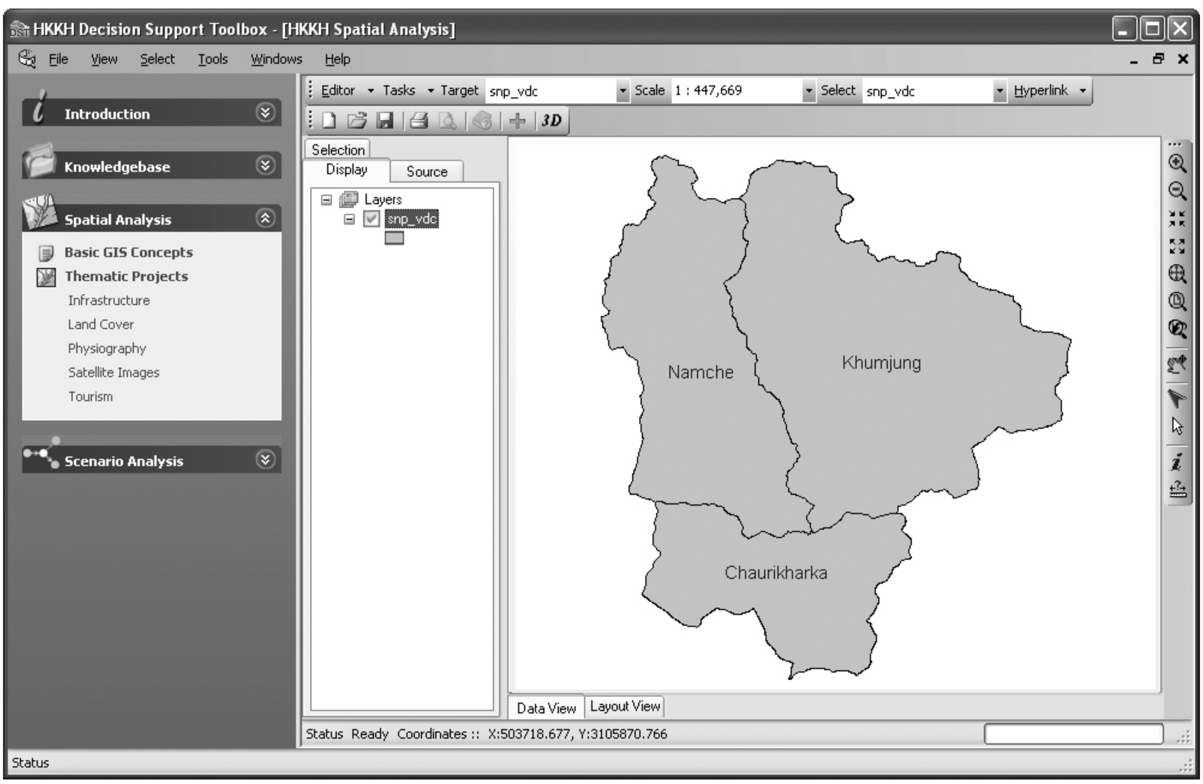
- Select Manual under **Method** drop-down in the Classification dialog.
- Set the upper bound value for each class under **Ranges** of **User Classify** section.
- Click **OK** to close the **Classification** dialog.
- **Click Apply to** view the symbology applied to the feature layer on the map window.
- Click **OK** to close the **Layer Properties** dialog.



4.4 Displaying labels

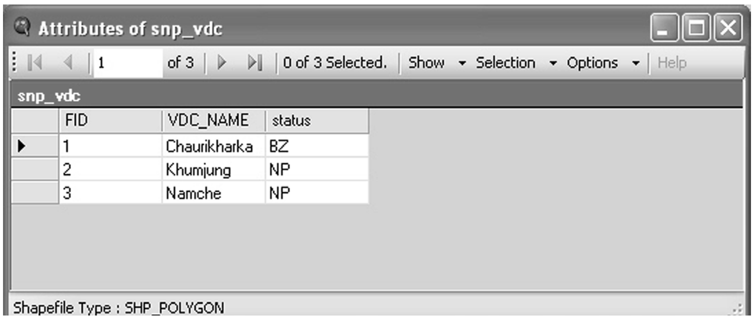


- If necessary, add a feature layer to the map.
- In the ToC, right-click the feature layer and click **Properties**.
- Click **Labels** tab.
- Set **Label features in this layer** on.
- Select the field that you want to use for labeling from the **Label Field** drop-down.
- If necessary, set the font, font-size and font-color for the labels.
- Click **Apply** to view the labels in the map.
- Click **OK** to close **Layer Properties** dialog.

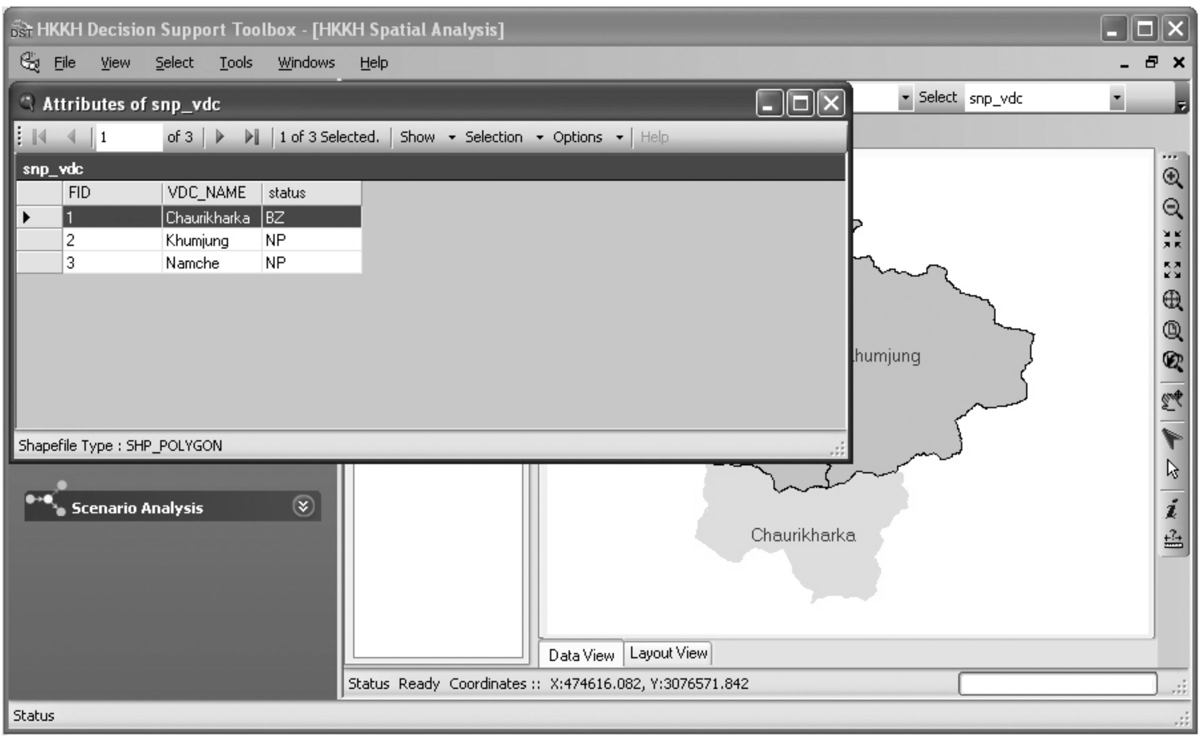


4.5 Working with attribute table of a feature layer

- If necessary, add a feature layer to the map.
- Right-click the feature layer in the ToC and click **Open Attribute Table** to view the corresponding attribute table.



- Select a record in the attribute table by clicking  at the left hand side of the record. Notice that the corresponding feature will be highlighted in the map.

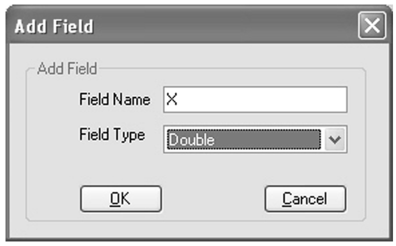


- Under **Show** menu, click **Selected** to view only the selected records. Next, click **All** under **Show** menu to view all the records.
- Under **Selection** menu, click **Zoom to Selected Features** to zoom to the selected features.
- Under **Selection** menu, click **Switch Selection** to switch the records selected.
- Under **Selection** menu, click **Select All** to select all the records in the attribute table.
- Under **Selection** menu, click **Clear Selection** to clear the selection in the attribute table.
- Under **Options** menu, click **Export Selected** or **Export All** to export the selected records or all the records of the attribute table to CSV format respectively.

4.6 Adding-Deleting field

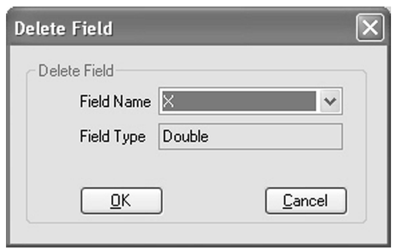
Adding field to an attribute table

- Open the attribute table of a feature layer as described in the earlier section.
- Under **Options** menu, click **Add Field.**
- In the **Add Field** dialog type the name of the field in **Field Name** textbox.
- Likewise, specify the field type from the **Field Type** drop-down.
- Click **OK** to add the field to the attribute table of the feature layer.



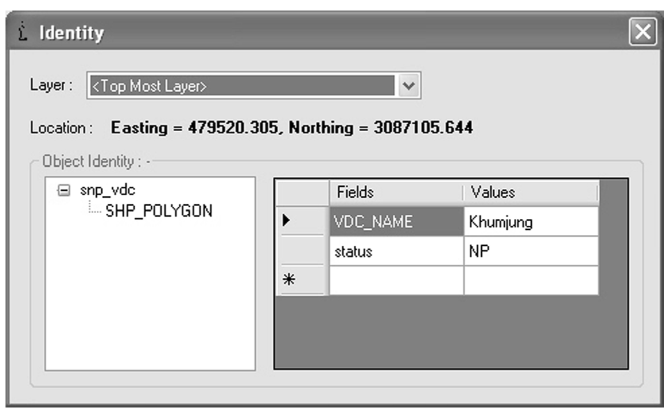
Deleting field from an attribute table

- Open the attribute table of a feature layer as described earlier.
- Under **Options** menu, click **Delete Field.**
- In the **Delete Field** dialog, select the field you want to delete from **Field Name** drop-down.
- Click **OK** to delete the selected field from the attribute table of the feature layer.



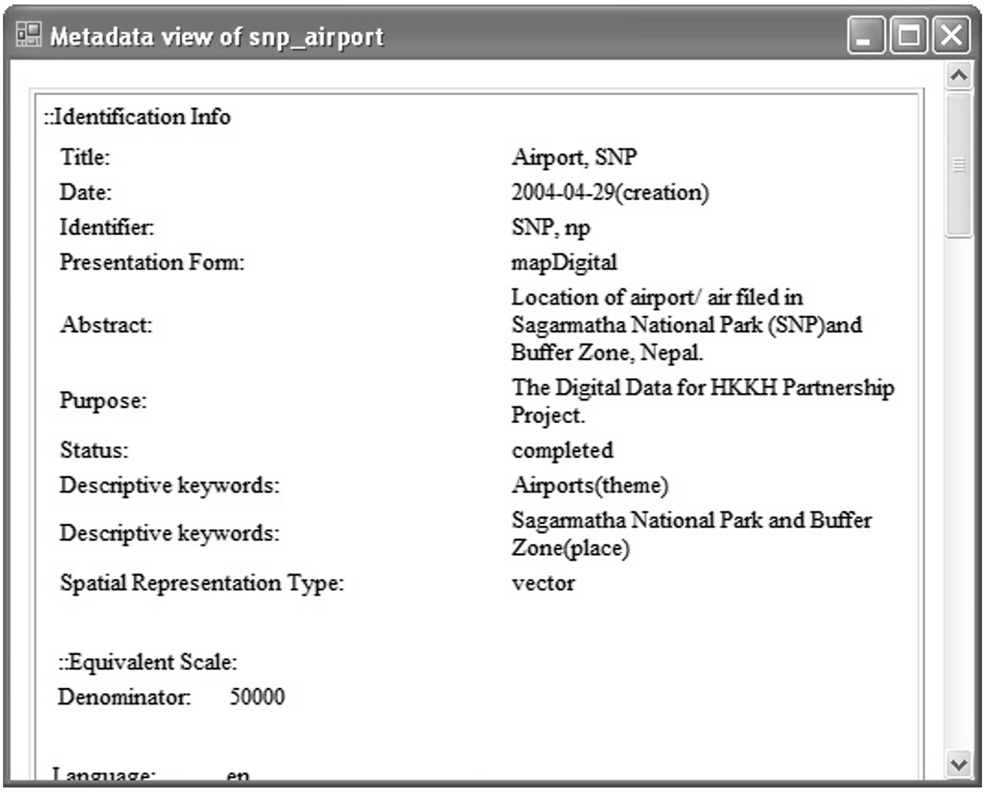
4.7 Identifying features

- Add a feature layer to SA if it does not have any layer in it yet.
- Click **Identity** tool in the standard GIS Tools. The Identify dialog will be opened.
- If the feature layer of your interest is not at the top in the ToC, click **Layer** drop-down and select *<Selectable Layer>* or alternatively select the feature layer of your interest.
- Click the feature on the map to view its attributes in the **Identify** dialog.



4.8 Viewing metadata of a feature layer

- In the ToC, right-click the layer.
- Click **View Metadata** to view the detailed metadata of this layer.

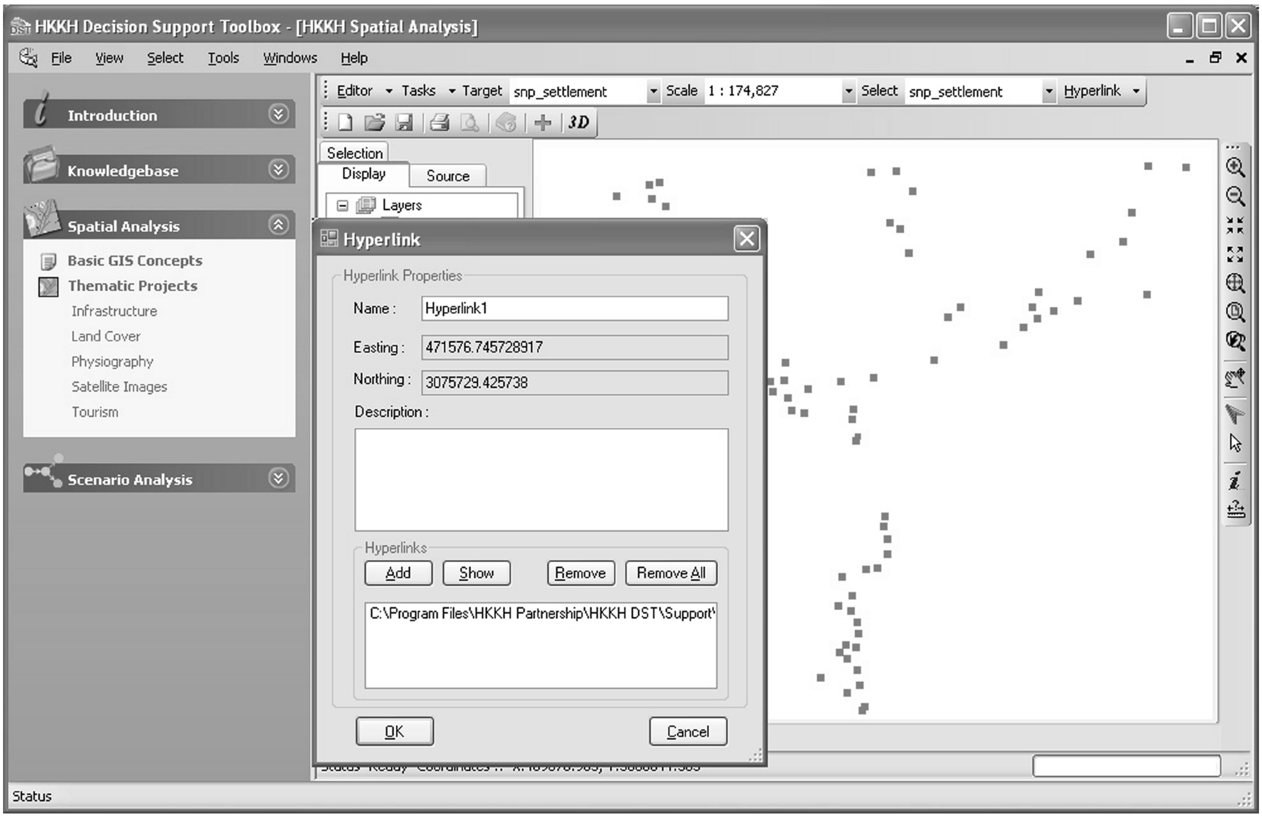


Note: The metadata of feature layer should conform to the metadata schema that the HKKH Partnership project uses for managing metadata of spatial data layers in its Knowledgebase system.

4.9 Working with Hyperlink tool

Adding hyperlink

- Add a feature layer to the map.
- Click **Add** from **Hyperlinks** menu in **Layer Toolbar** and click at a location where you want to add hyperlink. This will display Hyperlink dialog box with spatial coordinates information.



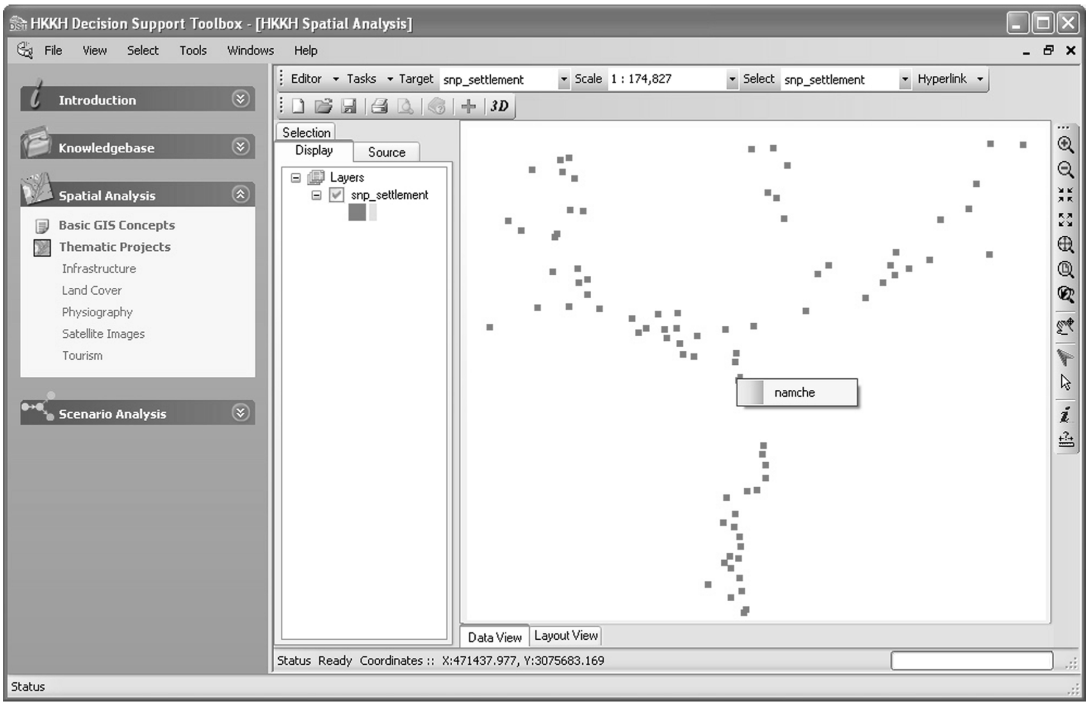
- Click **Add** button in the **Hyperlink** dialog and choose the document or picture in the **Open** dialog box. (for example, navigate ..*Support**Spatial Analysis**Sample Pictures* folder and choose namche. jpg). Repeat this step if you want to add more than one hyperlink to the same location.
- Click **OK** to finish creating a hyperlink. Notice that a yellow point mark is added to the map denoting that a hyperlink is present at that location.

Removing hyperlink

- Click **Remove** from **Hyperlinks** menu in **Layer Toolbar.**
- Click the existing hyperlink mark on the map to remove the hyperlink.

Viewing hyperlink

- Click **Hyperlink** under **Hyperlink** menu.
- Move your mouse pointer near to the hyperlink point mark. You will see a small popup window for the hyperlink.
- Click the hyperlink. It will open the hyperlinked object in the default software (e.g., word document in MS Word).

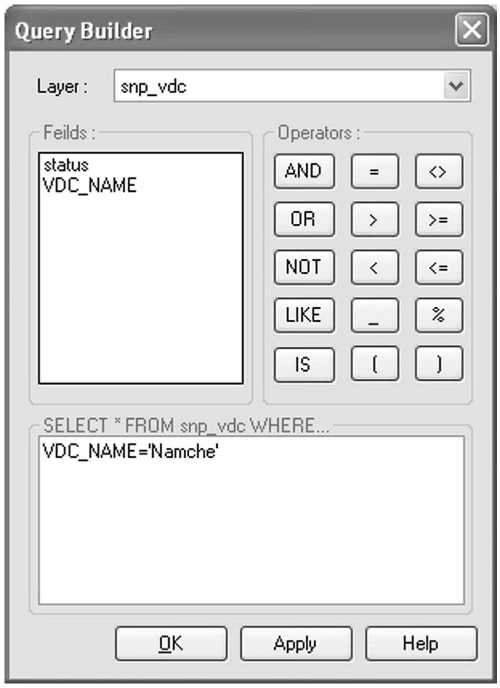


Editing hyperlink

- Click **Hyperlink** under **Hyperlink** menu.
- Click the hyperlink mark on the map to open the **Hyperlink** dialog.
- If you want to add more hyperlinks, click **Add** and create new hyperlinks following the steps described in *Adding Hyperlink* section.
- If you want to remove a hyperlink, select that hyperlink in the hyperlink-list and click **Remove**.
- If you want to remove all the existing hyperlinks, click **Remove All**.
- Click OK to apply the changes and close the **Hyperlink** dialog.

Note:

- Click **Hide** or **Show** under **Hyperlink** menu to show or hide hyperlink point marks on the map.
- The hyperlink is coordinates-based, meaning that one can add hyperlink at any given location of the map and it is not related to the feature of a given data layer. However, the SA requires that you have at least one feature layer present in the project for you to be able to create a hyperlink.
- You can create hyperlink to various kinds of information such as picture, document or html web pages and also, you can add more than one hyperlink to a given location.
- Whenever your mouse approaches the hyperlink mark, it pops up a small hyperlink window with list of hyperlinks. For this to happen, you need to be in the Hyperlink mode. You will be in Hyperlink mode when you click **Hyperlink** under **Hyperlink** menu.



4.10 Querying

- Click **Select by Attributes** under **Selection** menu. This displays a **Query Builder** dialog box.
- In the **Query Builder** dialog, double click the field in the field list to add it to the query text box and create a necessary query.
- Click **Apply** to execute the query. If the query is successful, you will see features selected in the map based on the query.
- Click **OK** to close the **Query Builder** dialog.
- Alternatively, open the attribute table of a feature layer and click **Select by Attribute** under Selection menu to query the feature layer.

4.11 Joining external table to feature attribute table

- In the ToC, right-click the feature layer and click **Join.**
- In the **Join Table** dialog, select the field of the feature layer based on which an external table will be joined.
- Browse to an external table (.dbf or .csv) that needs to be joined to the feature attribute table.
- Select the field in the external table that will be mapped to the already selected attribute field of the feature layer while joining.
- Click OK to join the external table to the attribute table of the feature layer.

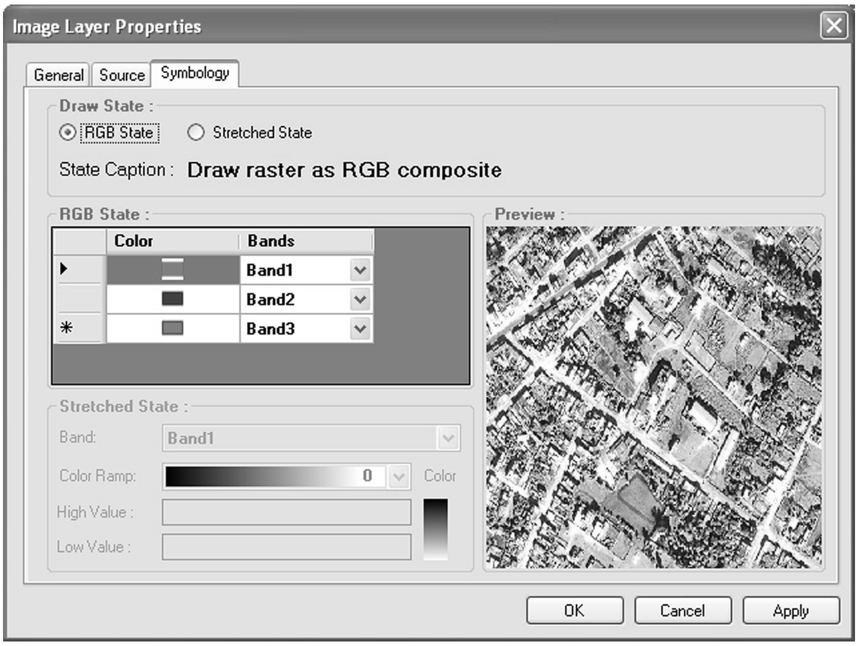
Note:

- To join successfully, the external table should have matching field in the feature attribute table.
- To remove the join, right-click the feature layer in the ToC and click **Remove Join**.

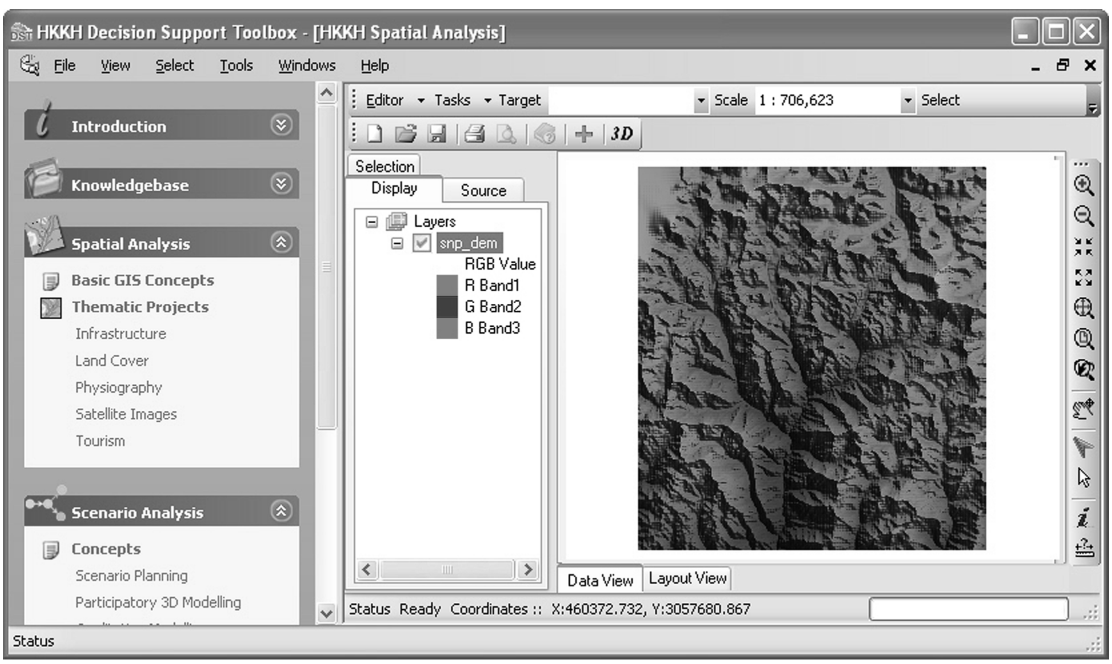
4.12 Working with raster layers

Symbolising raster layer based on RGB

- Add a raster layer to the map.

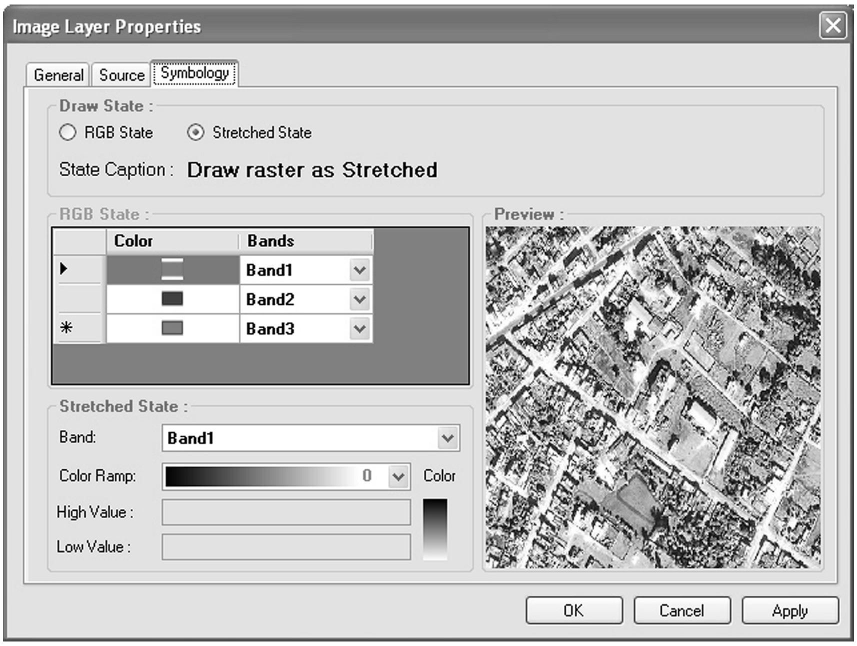


- In the ToC, right-click the raster layer and click **Properties**.
- Click **Symbology** tab.
  Choose the RGB State option.
- Assign three bands of the raster layer to Red, Green and Blue colors.
- Click **Apply** button to view the change in view of the image layer in the map.
- Click **OK** to close the **Image Layer Properties** dialog.

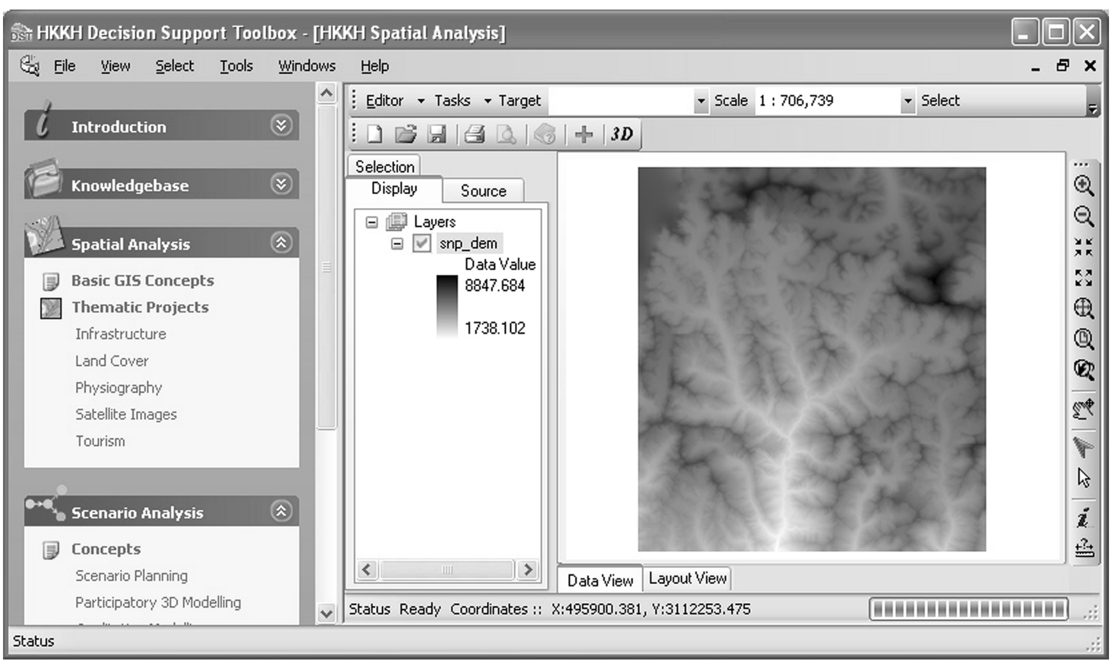


Symbolising raster layer based on grid values

- Add a raster layer to the map.
- In the ToC, right-click the raster layer and click **Properties**.

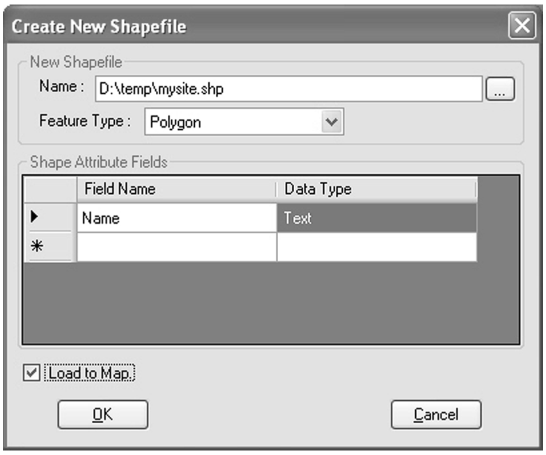


- Click **Symbology** tab.
- Choose the Stretched State option.
- Click **Band** drop-down and select band of the raster layer based on which the symbology is to be applied.
- Choose appropriate color ramp from **Color Ramp** drop-down.
- Click **Apply** button to view the change in view of the image layer in the map.
- Click **OK** to close the **Image Layer Properties** dialog.



4.13 Creating a new shapefile

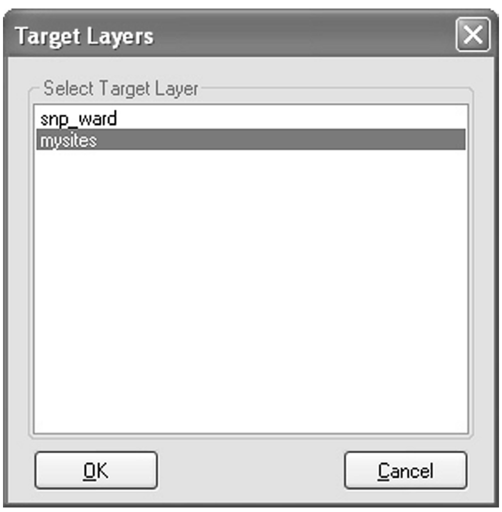
Creating a new blank shapefile

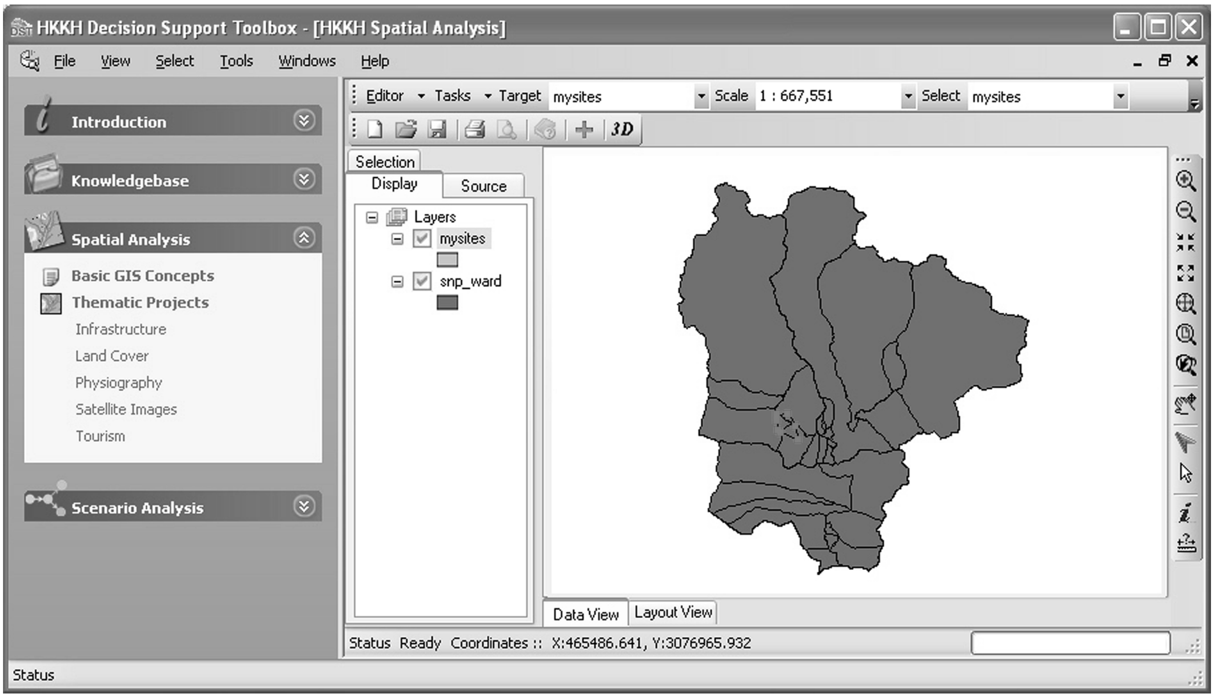


- Click **Create New Shapefile** from **Tools** menu.
- In the **Create New Shapefile** dialog, navigate to a location where you want to create the new shapefile and specify its name.
- Choose the feature type for the shapefile from the **Feature Type** drop-down.
- Type the names of the attribute fields for the new shapefile and specify their corresponding data types under **Shape Attribute Fields** group box.
- Set **Load to Map** on if you want to add the newly created shapefile to the map for digitisation.

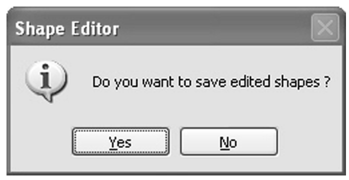
Digitising features

- Click **Start Editing** form **Editor** menu in the layer toolbar.
- Select the desired layer to edit in the **Target Layers** dialog and click **OK**.
- Click **Create Shape** under **Editor** menu. This will change the view mode to spatial feature editing/ digitising mode.
- Start digitising on the map to create the new features.

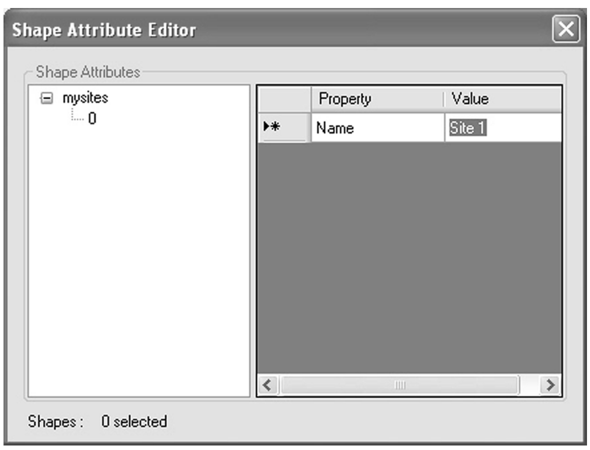




- To finish the digitisation just right-click.
- To finalise the digitising click **Stop Editing** under **Editor** menu.
- Click **Yes** in the confirmation dialog to save the digitisation.



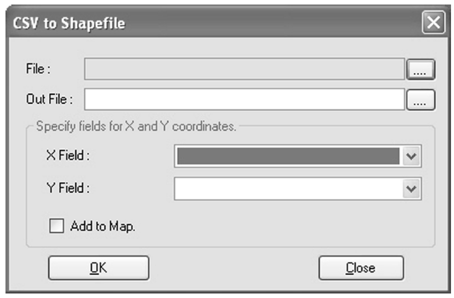
Editing attribute table



- Click Start Editing from Editor menu in the layer toolbar.
- Select the desired layer to edit in the **Target Layers** dialog and click **OK**.
- Click **Edit Attributes** under **Editor** menu.
- Next, click the feature on the map for which attribute information is to be edited.
- Change the field attribute value as required.
- Close the **Shape Attribute Editor** dialog.
- Click **Stop Editing** under **Editor** menu and click **Yes** in the confirmation dialog to save the editing.

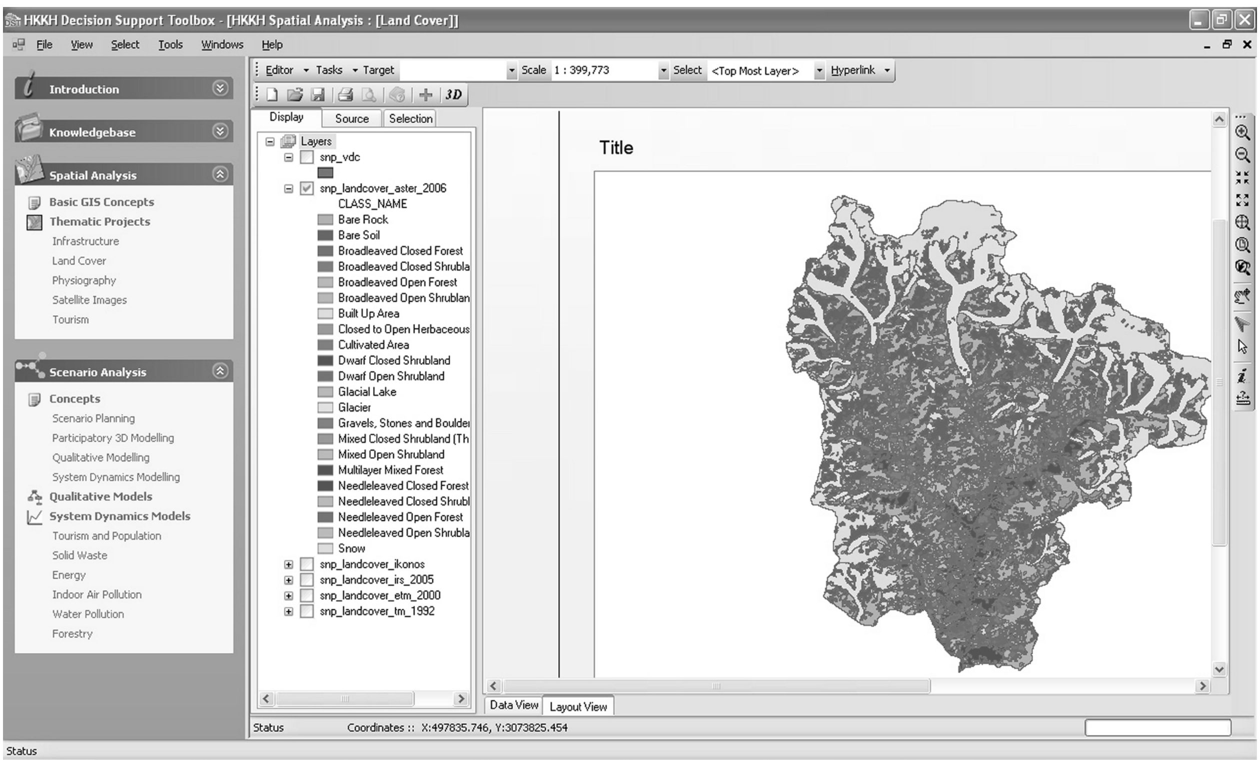
4.14 Creating a shapefile from Comma Separated Values or CSV file

- Click **CSV to Point Shapefile** from **Tools** menu.
- In the **CSV to Shapefile** dialog, navigate to your Comma Separated Values file or CSV file.
- Specify the name of the output shapefile.
- From the **X Field** drop-down, choose a field of CSV that corresponds to Easting coordinates.
- From the **Y Field** drop-down, choose a field of CSV that corresponds to Northing coordinates.
- Set **Add to Map** on to add if you want to add the newly created point shapefile to the map.
- Click **OK** to create the new point shapefile.

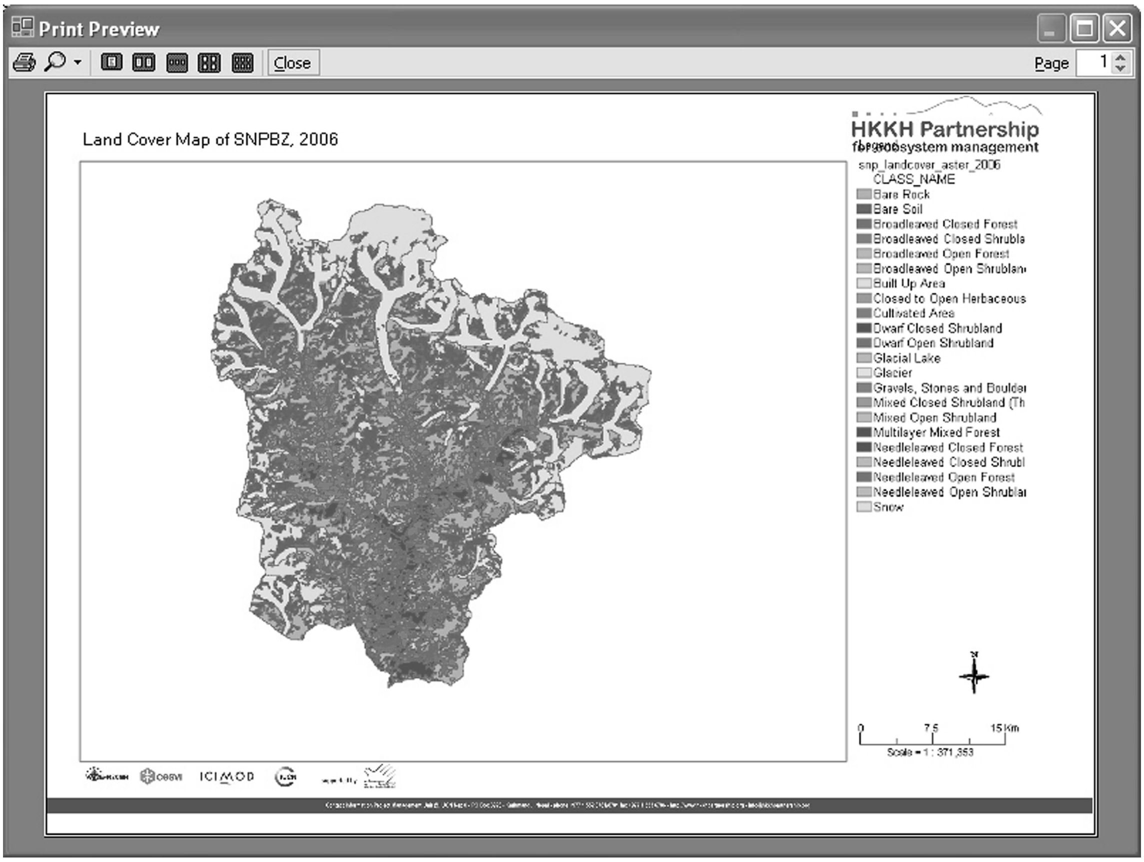


4.15 Layout and Printing

- The SA allows composing and printing maps in A4 paper size using the template provided.
- Add necessary data layers to a SA module.
- Set the appropriate symbology to the layers.
- Once the map is composed, switch to **Layout View** by clicking **Layout View tab** at the bottom left section of the Map Window. Alternatively, click **Layout View** under **View** menu to go to Layout View.



- Click **Print Setup** under File menu.
- Provide the title of the map in the Print dialog.
- Set the various components of maps such as Map Title, North Arrow, Legend, Scalebar on as appropriate. Click **Apply**.
- Click **Print Preview** to have a preview of the map before printing.

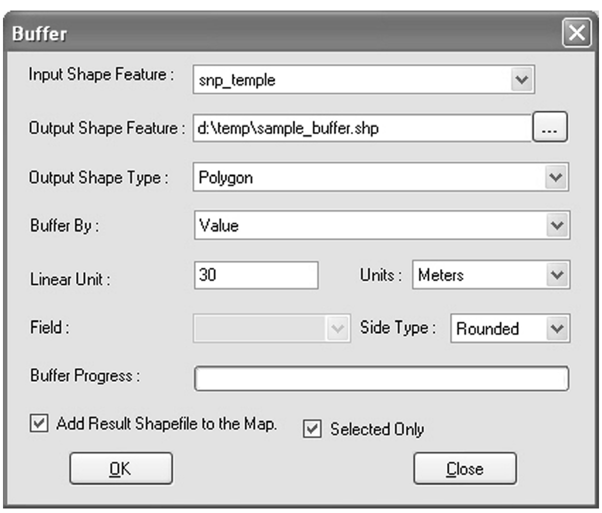


- In order to print the map, click **Print**.
- Click **Export Map** to export the map to different image formats (.jpg, .gif, .bmp).

4.16 Spatial operations

Buffering the shapefile and shapes

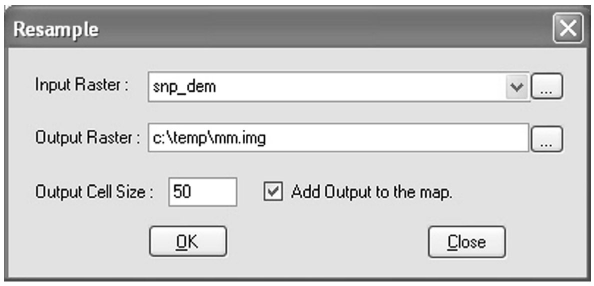
- Click **Tasks->Spatial Operations->Buffer** in the layer toolbar. This will display **Buffer** dialog.
- Select the feature layer to be buffered.
- Specify the name and location of the output shapefile.
- Choose the buffer method (Value or Field) from the **Buffer By** drop-down.
- Choose the units for buffering from Units drop-down.



- Type the buffering distance in **Linear Unit** textbox.
- Set the **Selected Only** option on if you want to use only selected features of the feature layer.
- Set **Add Result Shapefile to the Map** option on if you want to add the buffered shaepfile to the map.
- Click **OK** button to buffer.
- Click **Close** to close the Buffer dialog.

Resampling the raster grid (ERDAS Imagine format)

- Click **Tasks->Resample Grid** in the layer toolbar. This will display **Resample** dialog.
- Select or browse the input raster data layer.
- Specify the location and name for the re-sampled output raster layer.



- Give new cell size for output raster layer.
- Set **Add Output to the Map** option on if you want to add the output data layer to the map.
- Click **OK** to proceed to the re-sampling process.

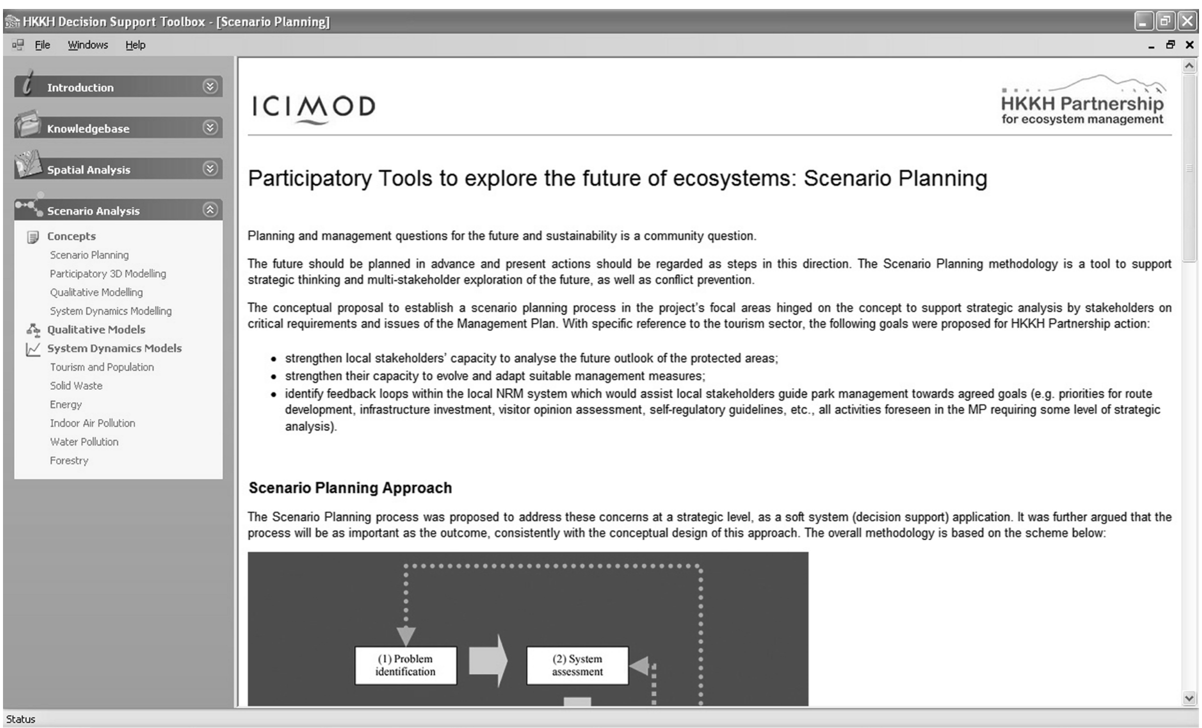
Scenario Analysis Module

The Scenario Analysis module contains two sub-modules:

- Qualitative Models
- System Dynamics Models

In addition to these sub-modules, the Scenario Analysis module also provides a brief introduction to various soft-system and hard-system tools used by the project such as scenario planning, participatory 3D modelling, qualitative modelling and system dynamics modelling.

- Click **Scenario Analysis** menu.
- Click **Scenario Planning** sub-menu. It will open a webpage giving a brief overview of scenario planning exercise carried out the by project.

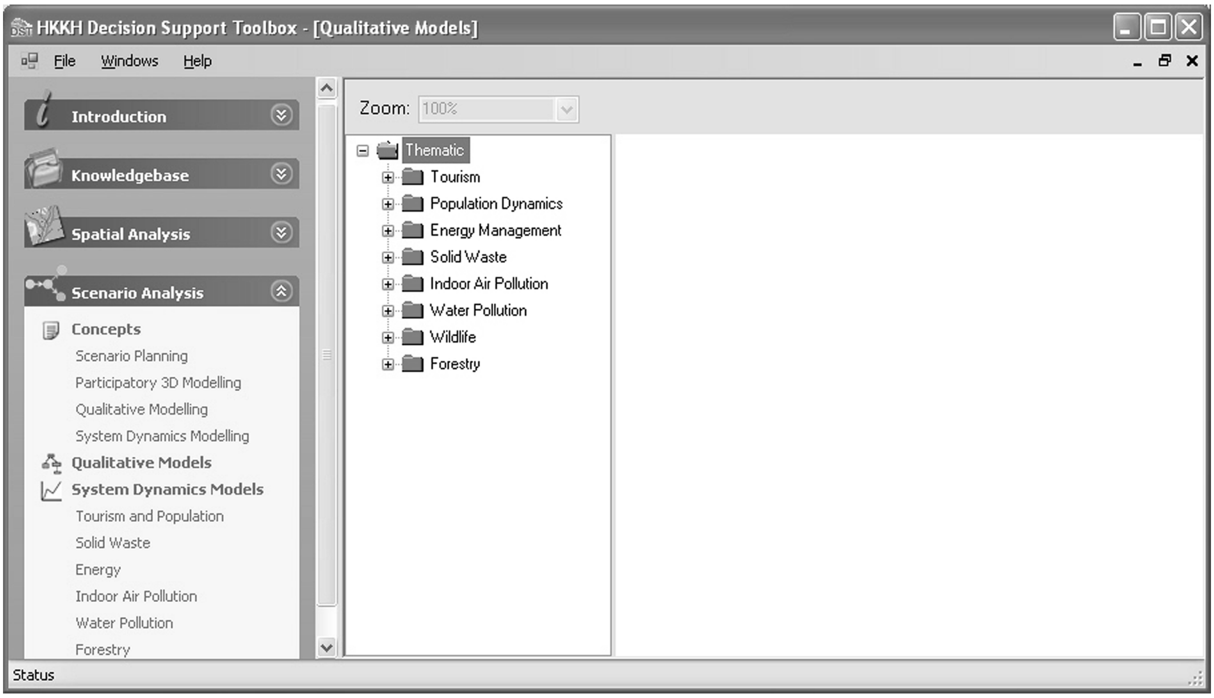


- Similarly, click other sub-menus to read the information on the corresponding topics.

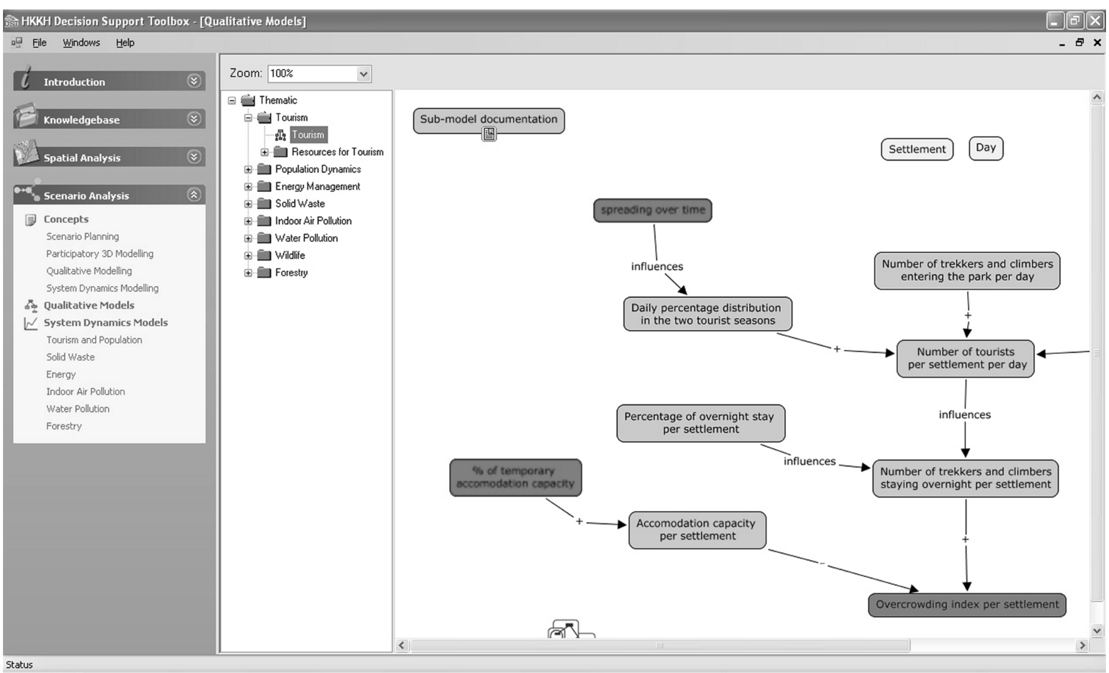
5.1 Qualitative Models

It allows browsing and viewing the qualitative models built in CMap software.

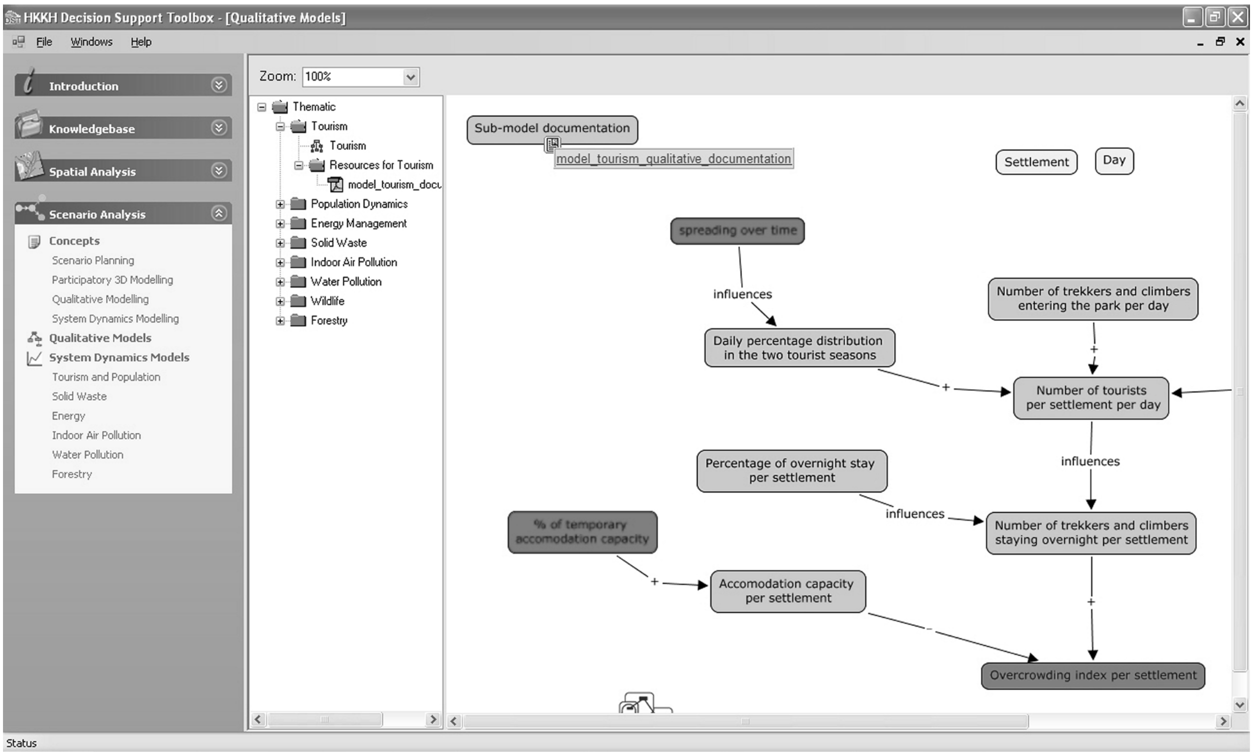
- Click **Scenario Analysis** menu.
- Click **Qualitative Models** vertical sub-menu to launch the Qualitative Models sub-module.



- Click the **+** next to the theme of your interest and click the model name. The qualitative diagram of the model will be then displayed in the browser on the right-hand side.



- View the model document by expanding the **Resources for MODEL_NAME** (e.g., Resources for Tourism). Double click any resource file of your interest to open it.



- Alternatively, click  on the qualitative diagram. This will show a hyperlink to the model document. Use this hyperlink to open the model document.
- The whole qualitative diagram usually does not fit in the browser window. So, use **Zoom** drop-down to zoom out and view more or whole model diagram in the browser window. Although it may be useful to view whole diagram in a single window sometime, the model components however may become too small to read.

5.2 System Dynamics Models

The System Dynamics Models sub-module allows users to load and run the system dynamics models, enabling them to adjust model parameters and policy levers so as to generate different scenarios over given time intervals with output linkage to GIS layers in Spatial Analysis module.

DST uses the Simile Scripting feature of Simile software for running Simile .sml system dynamics model. Therefore, for this sub-module to function, at least an evaluation version of Simile software should be installed in the user's machine.

The HKKH Partnership Project has developed a number of system dynamics models to address important management issues in SNPBZ. Please refer to chapters 6-12 for detailed information on those models and chapters 13-14 for steps to run those models from DST.

Tourism Model

6.1 Why was this model developed?

The development of the Tourist model addresses the problem of overcrowding in protected areas, which is considered a key management problem during the main tourist seasons.

The overall aim of this model is to support the users in analysing tourism dynamics in protected areas while assessing the overcrowding of tourists at settlements along the major trek itineraries in the study area.

In particular, the model was developed under the HKKH Partnership Project as a case study of the Sagarmatha National Park and Buffer Zone (SNPBZ). Through discussions held with local and national managers and experts, and research carried out in the framework of the Project itself, "overcrowding" has been identified by the management as a key problem during the tourist season.

The HKKH Partnership Project has developed and evaluated several management options that could contribute to solving these problems mainly by achieving a better distribution of tourists over time and space in SNPBZ. This model incorporates data obtained by two visitor surveys (2007-2008) carried out in the framework of the HKKH Partnership Project during the two major tourist seasons of autumn and spring.

The key variables influencing the overcrowding in the park have been defined as "management levers" of the model, which can be changed by the user to simulate different scenarios.

6.2 What is the context in which the model was developed?

Introduction

Tourism is one of the most promising economic sectors in Nepal. With a continuously growing flow of tourists, it has a huge potential for improving living conditions of Nepalese people.

The majority of tourism activities undertaken in the country relate to trekking, thus benefiting a considerable portion of the local population in the mountain regions, particularly lodges, tea shops, porters and agencies. The importance of the sector is very well documented by Sagarmatha National Park (SNP) where the number of tourists increased by three fold between 1986 and 2008.

Tourism in SNPBZ started with mountaineering activities soon after Nepal opened its borders to foreigners in 1950. However, Nepal received worldwide attention from international mountaineers and explorers when a native of New Zealand and Nepal became the first climbers to ever to reach the peak of Mt. Everest in 1953.

However, access to SNPBZ was still difficult and visitors had to hike for two weeks to reach Khumbu from Kathmandu. But this situation changed drastically in the 1970s when Lukla airstrip was built. Since then, the number of tourists has grown rapidly and tourism business has flourished in the region of SNPBZ, bringing about a fairly complex social transition. The number of tourists reached to about 3,000 in 1975 and grew over 700 percent (3,500 to more than 25,000) between 1975 and 2001.

Tourism has had both positive and negative impacts in these areas. Some of the negative consequences are disruption of the social and cultural fabric and local resources management systems, pressure on forests and pastures, growing waste disposal problems, decline in crop yields and cropping area and so on. The growth of tourism has made a positive impact in that it can uplift the general economic conditions of the remote areas of Nepal up to levels unknown in most of the country (CESVI, 2004). Therefore, the number of tourists as the main driver was not controlled because it is likely to have negative consequences on the livelihoods of many people dependent on the tourism industry both within and outside the boundary of SNP. The government also wanted to promote tourism as a strategy to reduce rural poverty. Many migrants are flocking to SNPBZ at increasing numbers because of lucrative income opportunities created by tourism. In addition, better socio-economic status of the local people has allowed many Sherpas to leave the Solu-Khumbu region for better opportunities out of the region or abroad.

However, if not properly managed, the huge influx of tourists could negatively affect the environment and jeopardise the long-term sustainability of the tourism sector, which is largely dependent on the quality of a pristine environment and on the various ecosystem.

The flow of migrants and tourists into the SNPBZ regions are the major drivers of change in the park. To better analyse the two phenomena, surveys on visitors, porters, migrants and lodge keepers have been conducted during the duration of the project. The survey on visitor's opinion unanimously pointed to crowding in the park as a major issue to be monitored and managed. Overcrowding can compromise the image of the park as the world's outstanding destination among trekkers and mountaineers in the long-term and discourage visitors, which can have a disastrous affect on the local economy. Therefore, the management of the park and its priorities has been documented as the SNP Management and Tourism Plan (2007-2012). The Plan suggests actions necessary to combat overcrowding and congestion of visitors within the park.

The Tourist model aims at capturing and analysing these dynamics in order to assess the OVERCROWDING INDEX within the park.

Qualitative analysis of the Tourism Model

The first step in the overall modeling process adopted under the HKKH Partnership Project has been the qualitative analysis of the socio-ecological system of SNPBZ on the basis of existing studies, expert knowledge and stakeholders (Salerno et al., 2009). In this context, a qualitative model on the flow of tourism in the SNPBZ was developed to document the influx of visitors in the park, as shown in Figure 1. The qualitative sub-model analyses the daily flow of tourists entering the park in each settlement and how this can be combined with the accommodation capacity within the park, which is crucial in reducing the overcrowding. Tackling the issue of overcrowding in the park is necessary to achieve the objective set in the current Management Plan of spreading tourist over space and time in the park.

As shown in Figure 1, the daily number of tourists in each settlement is determined by all the trekkers and climbers entering the park each day combined with both the daily percentage of distribution in the two tourist seasons and the percentage of tourists in each settlement.

Management policies can be addressed to encourage tourists to plan their trip within the park during the most critical tourist seasons (*spreading over time*) and along alternative routes and itineraries (*spreading over space*). Such management policies may influence the number of tourists during the two main tourist seasons and in each settlement.

After these policies have been implemented, an assessment of overcrowding in the park (*overcrowding index per settlement)* can be derived by considering the amount of tourists *(both trekkers and climbers)* who stay overnight in each settlement along with the accommodation facilities available in each settlement *(accommodation capacity per settlement)*.

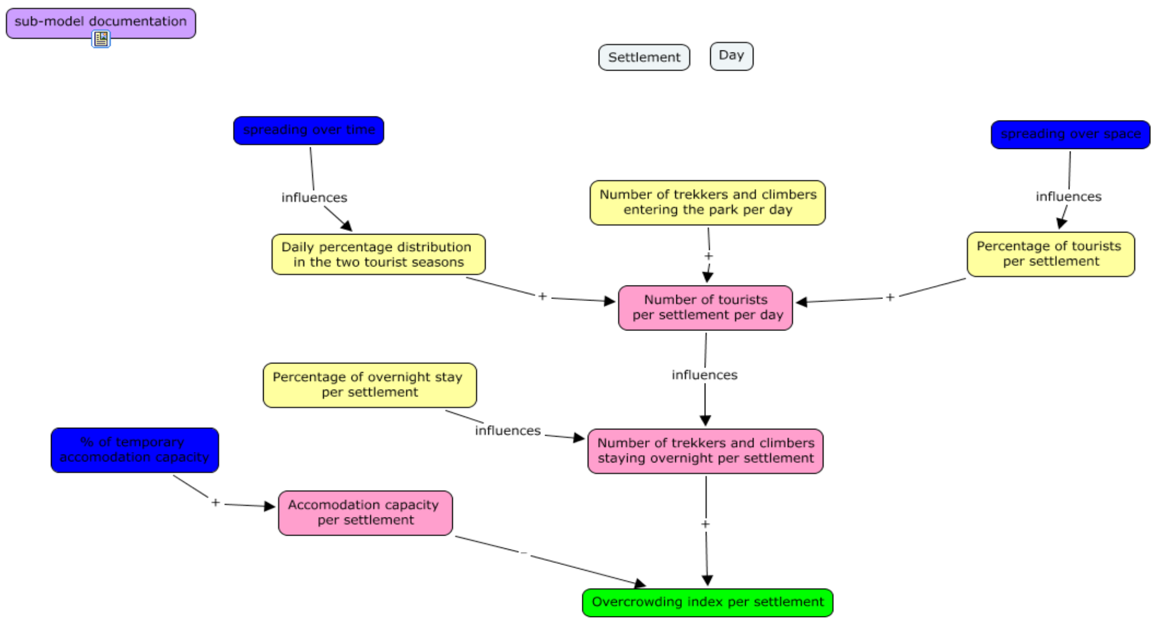


Figure 1: Qualitative diagram of the tourism model

6.3 How does this model work?

This Tourism model tracks the movement over time of every visitor in SNPBZ. It derives its numbers statistically and aggregates them based on survey data of the number of tourists entering the park, their probabilities of entering through different itineraries and so on, as explained later in this section.

The model considers climbing and trekking as two major tourist activities and incorporates 18 settlements along the 20 main touristic itineraries identified in SNPBZ: Chukung, Dingboche, Dole, Dzonglha, Gokyo, Gorakshep, Khumjung, Lobuche, Lukla, Machherma, Marlung, Namche, Pangboche, Phakding, Pheriche, Phortse, Tengboche, Thame

Particularly for the case study of SNPBZ, two visitor survey campaigns ensured the collection of important information on visitors entering the park from October 2007 to September 2008 during the two major seasons (Autumn and Spring) that shape touristic activities in this area. The autumn season is historically mainly dominated by trekkers and mountaineers activities in the lower peaks of the park while spring is dominated by a higher presence of climbers engaged in climbing mountain peaks, particularly Mt. Everest.

The surveys on visitors entering SNPBZ along the two major seasons of Autumn 2007 and Spring 2008 also identified and analysed major tourist itineraries in the park that encompass 18 different settlements. The information collected with the survey also included standard practices and traditional trekking routes proposed by guides, tour operators and agencies working in the area, leading to the identification of 20 major itineraries that people usually follow during their journey in the park. Both trekkers and climbers trek along the same routes and do not show a distinct difference in itineraries.

By documenting the major tourist itineraries within the park people staying overnight at settlements could be identified. This information is extremely useful when analysing congestion and overcrowding in the park as well as to understand the impact this has at different locations within the park every year.

The 20 itineraries identified are detailed in the following table including number of itineraries, itinerary names, total length of the trek (including total overnight stays) and the settlements visited during the journey. The settlements visited during the trip are given in order from the beginning till the end of the journey. The number of overnight stays in each settlement per trek itinerary is also provided.

Table 1: Major tourist itineraries in SNPBZ

No. of Itinerary	Itinerary name	Total No. of overnight stays	Settlements visited (No. of overnight stay in each settlement)
1	Renjo – Cho La - Kalapattar	15	Phakding (1) - Namche (2) – Thame (1) – Marlung (1) – Gokyo (2) – Dzonglha (1) – Lobuche (1) - Gorak Shep (2) - Pheriche (1) - Tengboche (1) – Namche (1) – Lukla (1)
2	Gokyo - Kalapattar via Phortse	15	Phakding (1) - Namche (2) - Khumjung (1) – Phortse (1) - Gokyo (2) - Dzonglha (1) - Lobuche (1) - Gorak Shep (2) - Pheriche (1) - Tengboche (1) - Namche (1) – Lukla (1)
3	Gokyo - Kalapattar via Dole	16	Phakding (1) - Namche (2) - Khumjung (1) - Dole (1) - Maccherma (1) - Gokyo (2) - Dzonglha (1) - Lobuche (1) - Gorak Shep (2) -Periche (1) - Tengboche (1) - Namche (1) – Lukla (1)
4	Gokyo - Kalapattar via Dole and Thame Valley	17	Phakding (1) - Namche (2) - Thame (1) - Khumjung (1) - Dole (1) - Maccherma (1) - Gokyo (2) - Dzonglha (1) - Lobuche (1) - Gorak Shep (2) - Periche (1) - Tengboche (1) - Namche (1) - Lukla (1)
5	Gokyo via Phortse	12	Phakding (1) - Namche (2) - Khumjung (1) - Phortse (1) - Gokyo (2) - Maccherma (1) - Dole (1) - Khumjung (1) - Namche (1) - Lukla (1)
6	Gokyo via Dole	12	Phakding (1) - Namche (2) - Khumjung (1) - Dole (1) - Maccherma (1)- Gokyo (2) - Phortse (1) - Khumjung (1) - Namche (1) - Lukla (1)
7	Phortse - Tengboche	9	Phakding (1) - Namche (2) - Khumjung (1) - Phortse (1) - Pangboche (1) -Tengboche (1) - Namche (1) - Lukla (1)
8	Tengboche – Kalapattar via Chukung and Periche	14	Phakding (1) - Namche (2) - Thengboche (1) - Periche (1) - Chukung (1)- Dingboche (1) - Lobuche (1) - Gorak Shep (2) - Pheriche (1) - Tengboche (1) - Namche (1) - Lukla (1)
9	Tengboche – Kalapattar via Chukung and Dingboche	14	Phakding (1) - Namche (2) - Thengboche (1) - Dingboche (1) - Chukung (1) - Periche (1) - Lobuche (1) - Gorak Shep (2) - Pheriche (1) - Tengboche (1) - Namche (1) - Lukla (1)
10	Tengboche – Kalapattar via Periche	12	Phakding (1) - Namche (2) – Tengboche (1) – Periche (1) Lobuche (1) – Gorak Shep (2) – Pheriche (1) – Tengboche (1) – Namche (1) - Lukla (1)
11	Tengboche – Kalapattar via Dingboche	12	Phakding (1) - Namche (2) - Tengboche (1) - Dingboche (1) - Lobuche (1) - Gorak Shep (1) - Pheriche (1) - Tengboche (1) - Namche (1) - Lukla (1)
12	Tengboche – Lobuche via Chukung	12	Phakding (1) - Namche (2) - Tengboche (1) - Dingboche (1) - Chukung (1) - Pheriche (1) - Lobuche (1) - Pheriche (1) - Tengboche (1) - Namche (1) - Lukla (1)
13	Tengboche – Lobuche	10	Pakding (1) - Namche (2) - Tengboche (1) - Periche (1) - Lobuche (1) - Pheriche (1) - Tengboche (1) - Namche (1) - Lukla (1)
14	Tengboche – Dingboche	10	Phakding (1) - Namche (2) - Tengboche (1) - Dingboche (1) - Lobuche (1) - Pheriche (1) - Tengboche (1) - Namche (1) - Lukla (1)
15	Thame	6	Phakding (1) - Namche (2) – Thame (1) – Namche (1) - Lukla (1)
16	Thame - Tengboche	8	Phakding (1) - Namche (2) - Thame (1) - Khumjung (1) - Tengboche (1) - Namche (1) - Lukla (1)
17	Khumjung - Tengboche	7	Pakding (1) - Namche (2) - Khumjung (1) - Tengboche (1) - Namche (1) - Lukla (1)
18	Tengboche - Pangboche	8	Phakding (1) - Namche (2) - Tengboche (1) - Pangboche (1) - Tengboche (1) - Namche (1) - Lukla (1)
19	Tengboche	6	Pakding (1) - Namche (2) - Tengboche (1) - Namche (1) - Lukla (1)
20	Only Namche	3	Phakding (1) - Namche (1) - Lukla (1)

The probability that a tourist chooses a particular itinerary has also been considered. The following tables provide the percentage distribution of tourists and climbers over each itinerary.

Table 2: Percentage distribution of tourists over the 20 itineraries identified in the SNPBZ

Distribution of tourists over itineraries			
	Itineraries	Tourists	%
1	Renjo – Cho La - Kalapattar	50	1.2
2	Gokyo - Kalapattar via Phortse	439	10.9
3	Gokyo - Kalapattar via Dole	396	9.8
4	Gokyo - Kalapattar via Dole and Thame Valley	129	3.2
5	Gokyo via Phortse	318	7.9
6	Gokyo via Dole	179	4.4
7	Phortse - Tengboche	382	9.5
8	Tengboche – Kalapattar via Chukung and Periche	149	3.7
9	Tengboche – Kalapattar via Chukung and Dingboche	54	1.3
10	Tengboche – Kalapattar via Periche	539	13.4
11	Tengboche – Kalapattar via Dingboche	228	5.7
12	Tengboche – Lobuche via Chukung	51	1.3
13	Tengboche – Lobuche	215	5.3
14	Tengboche – Dingboche	139	3.4
15	Thame	69	1.7
16	Thame - Tengboche	41	1.0
17	Khumjung - Tengboche	169	4.2
18	Tengboche - Pangboche	79	2.0
19	Tengboche	205	5.1
20	Only Namche	203	50
	total	4034	100 %

Source: CESVI, elaboration based on Visitor Survey in Sagarmatha National Park, Autumn 2007 and Spring 2008

Table 3: Percentage distribution of climbers over the 20 itineraries identified in the SNPBZ

Distribution of climbers over itineraries			
	Itineraries	Climbers	%
1	Renjo – Cho La - Kalapattar	77	15.2
2	Gokyo - Kalapattar via Phortse	5	1.0
3	Gokyo - Kalapattar via Dole	40	7.9
4	Gokyo - Kalapattar via Dole and Thame Valley	59	11.6
5	Gokyo via Phortse	9	1.8
6	Gokyo via Dole	22	4.3
7	Phortse - Tengboche	18	3.5
8	Tengboche – Kalapattar via Chukung and Periche	25	4.9
9	Tengboche – Kalapattar via Chukung and Dingboche	39	7.7
10	Tengboche – Kalapattar via Periche	10	2.0
11	Tengboche – Kalapattar via Dingboche	29	5.7
12	Tengboche – Lobuche via Chukung	12	2.4
13	Tengboche – Lobuche	13	2.6
14	Tengboche – Dingboche	32	6.3
15	Thame	48	9.4
16	Thame - Tengboche	5	1.0
17	Khumjung - Tengboche	3	0.6
18	Tengboche - Pangboche	13	2.6
19	Tengboche	21	4.1
20	Only Namche	28	5.5
	total	508	100 %

Sources: Paolo Caroli, elaboration based on Visitor Survey in Sagarmatha National Park, Autumn 2007 and Spring 2008

The model then runs and makes calculation of the OVERCROWDING INDEX for every consecutive day. The OVERCROWDING INDEX is the performance indicator of the model and shows how effective the combination (or single) management options chosen by the user are in addressing this problem.

6.4 The model inputs

Four different types of input data are considered in the Tourism model. They are:

- ARRIVALS: number of tourists entering in the park each day
- WHERE: settlement of overnight stay for each itineraries
- DISTRIBUTION: percentage of tourist distribution over 20 different itineraries
- PERMANENT ACCOMMODATION CAPACITY: amount of permanent accommodations in each settlement

All these variables vary also for type of activities, where in the case study of SNPBZ, main touristic activities are trekking and climbing. Each of the four input variables described above is connected with an input table in *.csv format, which are respectively indicated in the table here below:

Table 4: Input variable and connected input table.csv files

Input variable	Input table (*.csv format)
ARRIVALS	activity_timing.csv
WHERE	activity_itinerary.csv
DSITRIBUTION	activity_distribution.csv
Permanent accommodation capacity	permanent_accommodation.csv

A brief description of each input table is provided below:

Activity_timing.csv

The *activity_timing.csv* input table contains the daily arrivals of tourists in the park depending upon their activity (e.g., climbing or trekking for the case of SNPBZ).

The table is composed of three columns concerning:

- *Time* [Julian day]
- *Activity* [name]
- *Arrivals* (No. of tourists arriving in the park each day) [#]

Table 5: Example of activity_timing.csv input table for SNPBZ

Time	Activity	Arrivals
0	climbing	0
0	trekking	17
1	climbing	0
1	trekking	25
2	climbing	0
2	trekking	41
...	...	...
...	...	...

Activity_itinerary.csv

The *activity_itinerary.csv* input table contains information about overnight stay by each *activity* and by each itinerary.

The input table is composed of four columns:

- *Activity* (Type of activity) [name]
- *Itinerary* (No. of the itinerary) [#]
- *Stop* (Progressive number indicating the day itinerary) [#]
- *Where* [Settlement name of overnight stay]

For the specific case of SNPBZ, we provide an example on Table 6 concerning the itinerary No.1 (Renjo-Cho La-Kalapattar) envisaging 15 overnight stays.

Table 6: Number of overnight stays in each settlement along itinerary No. 1

Itinerary 1: Ren Renjo-Cho La-Kalapattar	Overnight stays
Phakding	1
Namche	2
Thame	1
Marlung	1
Gokyo	2
Dzonglha	1
Lobuche	1
Gorak Shep	2
Pheriche	1
Tengboche	1
Namche	1
Lukla	1
total	15

The *activity_itinerary.csv* table has to be structured considering not only the overnight stay in each settlement but also their sequence according to the itinerary. For instance, the following table shows that the climber will stay overnight at Gokyo on the 6th and 7th day.

Table 7: Example of activity_itinerary.csv input table for SNPBZ

Activity	Itinerary	Stop	Where
climbing	1	1	Phakding
climbing	1	2	Namche
climbing	1	3	Namche
climbing	1	4	Thame
climbing	1	5	Marlung
climbing	1	6	Gokyo
climbing	1	7	Gokyo
climbing	1	8	Dzonglha
climbing	1	9	Lobuche
climbing	1	10	Gorakshep
climbing	1	11	Gorakshep
climbing	1	12	Pheriche
climbing	1	13	Tengboche
climbing	1	14	Namche
climbing	1	15	Lukla
climbing	2	1	Khumjung
climbing	2	2	Phortse
...	...	...	...
...	...	...	...

Activity_distribution.csv
The a*ctivity_distribution.csv* table contains information about the probability that tourists (*Activity*) may choose different itineraries (the value ranges from 0 to 1).

The input table is composed by three fields:

- *Activity* [name]
- *Itinerary* (No. of the itinerary) [#]
- *Distribution* [probability distribution 0:1]

Table 8: Example of Activity_distribution.csv input table for SNPBZ

Activity	Itinerary	Distribution
climbing	1	0.1516
climbing	2	0.0098
climbing	3	0.0787
climbing	4	0.1161
climbing	5	0.0177
climbing	6	0.0433
...	...	...
trekking	1	0.0124
trekking	2	0.1088
...	...	...

Permanent_accommodation.csv

The p*ermanent_accommodation.csv* table contains data about the accommodation capacity (depending on number of beds) of each settlement.

The input table is composed of two fields:

- *Settlement* [Settlement name]
- *Base capacity* [# of bed]

Table 9: Example of input permanent_accommodation.csv table for SNPBZ

Settlement	Base Capacity
Chukung	108
Dole	122
Dingboche	587
Dzonglha	60
Gokyo	188
Gorakshep	203
Khumjung	445
Lobuche	259
Lukla	1542
Machherma	139
...	...
...	...

6.5 Management levers

The Tourism model was developed with a specific objective in mind: exploring different solutions to mitigate the problem of overcrowding during the two tourist seasons in SNPBZ. In order to identify and adopt the proper management levers as well as the performance indicator/s, several workshops with managers were held during the qualitative analysis step within the modelling process. Consequently, the following management levers were identified for SNPBZ, including both qualitative and quantitative policies (reported in the following table), though among these only the quantitative ones has been implemented in the model afterward.

Table 10: Tourism model management levers and their characteristics for SNPBZ

Management lever name	Brief description	type	Variable	Value of the variable
Spreading visitor flows over time	Visitors concentrate over two main seasons in SNPBZ (beginning of March-end of May; beginning of October – end of November). To reduce overcrowding in the park, tourists can plan their visit during less crowded periods within the two main seasons.	quantitative	Arrivals (A): Number of tourists entering in the park per day.	Int [No.]
			% tourism flow variation: percentage of increase / decrease of total number of tourists	Int [%]
Promotion of SNPBZ		qualitative	-	-
Fee policies		qualitative	-	-
Spreading visitor flows over space	Visitors concentrate mainly over trekking route to Everest-Base Camp. Promotion of alternative itineraries and cultural trek can reduce the congestion in the park.	quantitative	Distribution (D): distribution of visitors over itineraries	Real [No. 0:1]
Increase total accommodation capacity by using tents	Capacity of accommodation facilities in each settlement, regarding number of beds.	quantitative	Percentage increase (%_increase): percentage of increase of accommodations capacity per settlement	Int [%]

Possible solutions were conceived to center around policies that affect the distribution in time and space. Looking at the table, “fee policies” and “promotion of SNPBZ” act as separate management levers, while “spreading tourist flows over time” and “spreading tourist flows over space” are management/policy objectives rather than levers. Consequently “fee policies and “promotion of SNPBZ” could be seen as qualitative management or policy levers to achieve the objectives “spreading tourist flows over time” and “spreading tourist flows over space”.

Currently, three quantitative management levers are envisaged in the Tourist sub-model and can be categorised as follows:

- *Spreading visitor flows over space*, indicated through the variable *Distribution* (D) in the quantitative model.

This management lever is a combination of policies, promotions, infrastructure constructions and awareness raising campaigns aimed at attracting alternative itineraries for tourists. The *Distribution* variable is both a management lever and an input data and it affects the system behaviour through changes in the allocation of tourists to the 20 different itineraries

- *Spreading visitor flows over time*, indicated through the variables *Arrivals* (A) and *% tourism flow variation* in the quantitative model.

  This management lever is a combination of policies and promotion actions aimed at informing visitors of overcrowding peaks and suggesting them to take into consideration that information while planning their trips. In fact, redistributing the flow of tourists from the autumn to the spring season could be the most immediate and appropriate choice to reduce congestion and overcrowding in the park during its most critical period.

  The *Arrivals* variable is both a management lever and an input data either. This policy concerns the number of tourists in each settlement and may vary while changing the time distribution and the total amount of tourists in the park.

  Regarding the variable *% tourism flow variation,* the application of this management lever influences the total amount of tourists entering in the park, which can be increased or decreased by the user by changing the total number of visitors per year by setting a %-value.

Table 11: Detail specification of management levers

Lever name and time scale	Specification	Variable	Unit and Description
Spreading visitor flows over time: Trend	Changing the total number of visitors per year by setting a %-value. The distribution of visitors remains unchanged by this lever, but is defined by the following levers:	% tourism flow variation	% change of visitor numbers per year (accumulation)
Spreading visitor flows over time: Seasonal variation (This lever is applied ALTERNATIVELY to the "daily numbers" below)	Defining a percentage value (increase or decrease) of the weekly visitor totals. The daily distribution within the week remains unchanged. The absolute daily numbers are recalculated by using the existing daily distribution within a week and the new weekly total set by a positive or negative %-value. This modification can be carried out for all weeks of the year. This transformation is carried out outside of Simile	arrivals	% change of weekly visitor totals
Spreading visitor flows over time: Weekly variation - daily numbers (This lever is applied ALTERNATIVELY to the "seasonal variation" above)	Manually setting/resetting the total daily numbers of visitors and trekkers. Default values are the ones obtained by the visitor survey. This is done in the csv-table before opening and running the model	arrivals	Total number of visitors (climbers and trekkers) per day

- *Temporary increase accommodation capacity*, indicated through the variable *Percentage increase* (%_increase) in the quantitative model.

This management lever allows the possibility of increasing temporary accommodation capacity in each settlement in the park expressed in terms of percentage. The values to be changed therefore refer to the total number of beds (sum of the capacity of all accommodation facilities) for every settlement and are percentages (not absolute numbers).

By setting or changing model input parameters that are connected to specific management levers, the user can simulate different scenarios, in other words, hypothetical situations that provide insights about the changes affecting the system if specific management levers were put in place. The management levers were developed in collaboration with local and national stakeholders and experts to ensure that they reflect viable options for improving the management of SNPBZ that are worthwhile to explore by means of simulating hypothetical scenarios. They are key determinants of the overcrowding problems: the number of visitors entering the park (*spreading visitor flows over time*), the percentage of visitors following the different trekking routes (*spreading visitor flows over space*) and the accommodation capacity in the settlements (*percentage of temporary accommodation capacity)*.

The effect of the user-defined management lever settings on the system can be assessed by looking at the changes of the system's "performance indicator" over time. The performance indicator is explained in detail in the model output section below.

Management lever "Spreading visitor flows over time":

To face an increasing number of visitors entering the park, managers and concerned institutions set in place several measures aiming to spread visitors over time. The months that are receiving fewer visits are promoted through marketing and advertisement campaigns with the objective of shifting the attention of visitors away from peak periods.

At the same time, spring season is advertised and promoted more than autumn in order to achieve a more balanced level of visits between the two main seasons. The measures adopted to spread the flow of visitors over time can include:

- differentiation of cost of tickets according to season and period
- limitation of visits according to a threshold established for every week throughout the year
- introduction of a compulsory system of reservation

The effect of all these measures is a change in the number of visitors entering the park (increase, decrease, different distribution or limitation).

By default, the model will run with the empirically determined number of trekkers and climbers who entered SNPBZ during the autumn season of 2007 and spring season of 2008 (status quo scenario). The data was collected by Cooperazione e Sviluppo (CESVI) in the framework of the HKKH Partnership Project through a survey carried out in these seasons.

With a specific policy (for example one of those outlined above) and the desired effect on the number of visitors entering the park over time, the user can use % TOURISM FLOW VARIATION lever to custom set the amount of visitors entering the park every day (365 days per year) by changing the values for CLIMBERS IN and TREKKERS IN in the respective input table assuming an increase in the percentage of each daily value for each consecutive year.

Management lever "Spreading visitor flows over space":

Historically the different valleys and places of the park are unevenly visited and visitors tend to concentrate along some major trekking routes. This is producing an unbalanced distribution of tourists within the park and posing a serious threat to resources and environment due to excessive degradation in some particularly critical locations.

Management of services becomes problematic due to the excessive number of tourists staying in one place at any moment of time. Waste is posing a serious threat to the environment as existing management schemes are not able to cope with the excessive number of people concentrating in particularly crowded areas.

To overcome these problems, park managers can set in places several measures in order to modify distribution of tourists within the park. These measures can include:

- information on level of crowding is provided to entering tourists favouring the selection on alternative routes
- alternative trekking routes are promoted and marketed benefiting the places that are less visited and receive few tourists
- new attractions are proposed in locations still untouched by the majority of the visitors
- cultural trekking and sightseeing are promoted in those valleys and spots that are receiving less visitors

This management lever will allow the user to modify the pattern of distribution of visitors along trekking routes and changing the values for CLIMBERS ITINERARY DISTRIBUTION and TREKKERS ITINERARY DISTRIBUTION in the respective input table.

This table contains the visitor-percentage-values for each trekking route, to be set as a value between 0 (no visitors) and 1 (100% of all visitors) for trekkers and climbers separately. The total of all values must add up to 1 (100%). The trekking routes differ in length and different trekking routes require different amount of days to complete. The section “how does this model work?” explains the number of days required by each trekking route identified for the SNPBZ (20 itineraries). It is important to keep in mind that assigning a percentage of visitors to a particular route implies that the same percentage of visitors stay the required amount of days in the park. CESVI has empirically determined what percentage of visitors stay for how long in the park. By default, the table with the empirically determined values is used.] Findings regarding lengths of stay in the park for different visitor groups is available in CESVI’s research report. Note that if the distribution of the visitors over the itineraries is changed by the user, the total number of visitors staying in the park at a given time is implicitly altered. It is recommended to assess the extent of this alteration when using this management lever in order to correctly interpret the results (performance indicator: overcrowding).

Management lever “Increased accommodation capacity”

Due to disposition of the park’s trekking routes and location of its major attractions, some places receive a great number of visitors that surpasses accommodation capacity in that area. Modifying management levers with different scenarios that allow the spread of tourists over time and space (Management lever 1 and 2) will reveal information about the most critical locations (settlements) and the source of the problem of overcrowding, as explained below:

- where are the places with the major need to increase accommodation capacity;
- which are the periods when this accommodation should be increased;
- for how long accommodation capacity should be increased in any given place.

Based on these insights, the management lever ACCOMMODATION CAPACITY allows the user to change the number of beds per settlement (positively or negatively) through the establishment of additional temporary accommodation space and by modifying the respective table with the number of beds available per settlement.

6.6 The model outputs

Indicator of performance

The Tourism Model has one major output or performance indicator called OVERCROWDING INDEX. This value is calculated by dividing number of tourists to number of bed capacity for any given settlement and on any given day. The value of the indicator above 1 indicates that a higher capacity would be required, resulting in a shortage of accommodation in the settlement(s) of interest. A value below 1 indicates an abundance of accommodation spaces. The value above and below 1 indicates the severity of the shortage and abundance of accommodation respectively. For example: a value of 0.90 indicates a 10% abundance in accommodation space, a value of 1.1 indicates an inability to host 10% of the visitors intending to stay overnight.

Other outputs

The Tourism flow model also provides the following outputs:

- Activities total here (Intermediate variables)
- ARRIVALS (Input data)
- DATE

For the SNPBZ, these outputs, including the performance indicator (i.e., OVERCROWDING INDEX), can be exported as a table composed by records for each day and by including the following columns:

Table 12: Output variables of the tourism model

Output variable	Index 1 (settlement)	Index 2 (activity)	Description
DATE [Julian day]			Simulation day
ARRIVALS [No.]	Chukung	climbing	Number of climbers entering in the park each day
		trekking	Number of trekkers entering in the park each day
	Dole	climbing	Number of climbers entering in the park each day
		trekking	Number of trekkers entering in the park each day
	…	…	…
Activities total here [No.]	Chukung	climbing	Number of climbers each day in Chukung
		trekking	Number of trekkers each day in Chukung
	Dole	climbing	Number of climbers each day in Chukung
		trekking	Number of trekkers each day in Chukung
	…	…	…
Overcrowding index [%]	Chukung		Overcrowding index each day in Chukung
	Dole		Overcrowding index each day in Dole
	Dingboche		Overcrowding index each day in Dingboche
	...		...

6.7 Bibliography

CESVI, 2004. *Review and discussion points on social factors of change in the Sagarmatha National Park and Buffer Zone*. Technical report. HKKH Partnersship Project.

ICIMOD. 2007. *Monitoring of visitor flows in Sagarmatha National Park. Use case, system specifications and general system analysis*. HKKH Partnership Project, International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal.

Caroli, P. and S. Giacco, 2007. *Visitor survey and monitoring of visitor flow in Sagarmatha National Park*. Preliminary study and preliminary design. HKKH Partnership Project, Working papers.

Salerno, F., E. Manfredi and S. Thakuri. 2009. *Conceptual modeling of socio-ecosystems: methodological framework and analysis of Sagarmatha National Park (Nepal) key dynamics (HKKH Partnership Project)*. Ev-K2-CNR. 101 pp.

Sherpa. L.N., 2006. *Sagarmatha National Park Management and Tourism Plan 2006-2011*. Department of National Parks and Wildlife Conservation (DNPWC), Sagarmatha National Park, Namche, solukhumbu.

Chapter 7

Population Dynamics Model

7.1 Why was this model developed?

The increased flow of tourists and number of inhabitants in the Sagarmatha National Park and Buffer Zone (SNPBZ) is an important phenomenon to consider because of the effects they have on environmental resources (waste production, pollution, exhaustion of the fuel, etc.).

The aim of this model is to analyse the dynamics of population in the protected areas, such as the SNPBZ with the overall objective of assessing the magnitude of the phenomenon especially during the main tourist seasons where the pressure on natural resources due to an influx of tourists constitutes a significant management concern.

7.2 What is the context in which the model was developed?

Introduction

The area of SNPBZ has been historically a conduit for migration. According to Oppitz (quoted in: Stevens, 1996), the original migration of Sherpa people from the Tibetan region of Kham to Khumbu took place between the 15th and the 16th century. According to Stevens (Stevens, 1996), there is evidence in the Khumbu oral traditions of conflicts between the Sherpa and the Rai, which testifies to the presence of the Rai ethnic group in the Solu-Khumbu region at the time of the Sherpa immigration.

Since this period of initial migration and potential conflict, the area has been inhabited by the Sherpa people and they have integrated their spiritual and cultural practices over the centuries. The closing of the frontier by China dramatically reduced the cross-border traffic between Tibet and Nepal, abruptly shifting the movement of the population across the frontier. More recently, new economic dynamics made affordable by tourism and new employment opportunities are changing the livelihoods and cultural and social fabric of the Sherpas. Changes have included: 1) new investment and business activities that bring new scenarios and redefine the idea of migration in SNPBZ; 2) improved quality in lodges and facilities; 3) new tendencies in tourism sector and market.

This trend is also causing immigration of non-Khumbu Sherpa into the area for livelihood opportunities, as evident in the management plan of the park, where an estimated 1,301 are defined as temporary residents who moved into SNPBZ from outside. These individuals encompass government employees, army staff, teachers, hotel and shopkeepers, outside economic migrants, business developers and speculators (SNP, 2005).

Migration in Khumbu is two-way, characterised also by out-migration. Many Sherpa residents are moving to Kathmandu and abroad to maintain and develop their businesses, or simply to escape harsh conditions in the coldest months of the season.

The major issues related to these trends can affect the ecosystem management as well as the resource and park management. The management plan strongly recommends that migration and its effects on the park should be monitored and taken into serious consideration. In particular, it calls for developing reliable baseline information on human population in addition to a system of registering local people, which will be maintained by the Buffer Zone and VDC organisations. Both will therefore monitor in-and-out migration over spatial and temporal scales (SNP, 2005).

This new and recent phenomenon deserves attention and reliable data is required to better understand trends, magnitude and potential problems caused by these rapidly changing migration dynamics. Understanding the forces that are behind the migration dynamics is therefore essential to better plan and set future priorities in management activities. Consequently, to define and understand this phenomenon, an analysis of the population dynamics in the SNPBZ is envisaged through this model.

Qualitative analysis of the Population Dynamics Model

The first step in the overall modeling process adopted under the HKKH Partnership Project has been the qualitative analysis of the socio-ecological system of SNPBZ on the basis of existing studies, expert knowledge and stakeholders (Salerno *et al.*, 2009). In this context, a qualitative diagram on population dynamics in the SNPBZ (Figure 2) was developed to analyse how the growth of tourists and inhabitants are affecting the ecosystem in the area. The final objective is to calculate the number of daily local population (*Number of local population*), which is calculated as the sum of the inhabitants of each settlement and the number of guides and porters per each trekker and climber entering the park every day.

As illustrated in Figure 2, the number of resident population (i.e., *settlement population*) depends on the yearly rates of birth and death as well as of immigration and emigration flows. Particularly, the birth rate and the immigration phenomenon give rise to the number of resident population and on the contrary, the death rate and emigration flows cause its decrease.

Furthermore, the number of guides and porters that accompany each visitor (mostly trekkers and climbers) entering the park is also considered and their numbers increase with the number of trekkers and climbers per settlement.

The integration of the number of resident population with the number of guides and porters per settlement determines the *Number of local population* in each settlement. This data is crucial also for many other sub-models in which human migration plays a significant role in changing the socio-ecological dynamics of a region.

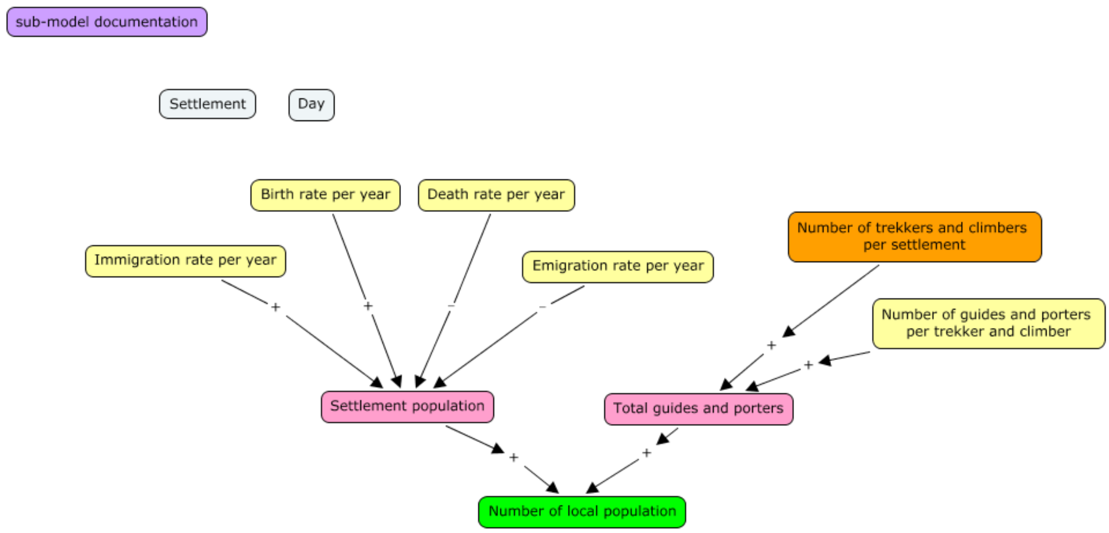


Figure 2: Qualitative diagram of the population dynamics model

7.3 How does this model work?

This model has been developed on the case study of SNPBZ to analyse the dynamics of local population in the park. Particularly, the model calculates the total number of the people present in each of the 18 selected settlements of the studied area as the sum of both local inhabitants (*Settlement population)* and guides and porters that are dependant on the number of tourists entering the park each day.

The number of *Settlement population* is regulated by birth and immigration flows (dependent on BIRTH and IMMIGRATION RATE) and on death and emigration flows (dependent on DEATH and EMIGRATION RATE).

In this way, we can calculate and estimate the total daily number of people present in each selected settlement. Then this information is integrated wit the other models allowing the user to analyse and estimate the impact of these statistics on the socio-ecosystem of the region.

7.4 The model inputs

The Population dynamics model envisages the following input variables:

- RATES: this variable includes:
- BIRTH RATE (b): this variable represents the average year birth rate of the population analysed;
- DEATH RATE (d): this variable represents the average year death rate of the population analysed;
- IMMIGRATION RATE (i): this variable represents the average year immigration rate of the population analysed;
- EMIGRATION RATE (e): this variable represents the average year immigration rate of the population analysed;
- STAFF PER ACTIVITY: this variable represents the number of local staff (e.g., guides and porters for the SNPBZ) supporting each category of tourists (e.g., trekker and climber for the SNPBZ);
- SETTLEMENT POPULATION initial value (P_sett): this variable represents the number of local population inhabiting in the settlement at initially (time 0).

Furthermore, beside the above variables where users can directly intervene, the Tourism flow model provides other input variables, namely NUMBERS OF TOURISTS, which is a sum of the total number of tourists in each category per activity.

The values and units of each variable used for the case of SNPBZ are indicated in the Table 13 below:

Table 13: Input variables for SNPBZ with specifications of units, values and data sources

Input variable	Unit	Value for SNPBZ	Data source
Birth rate	No./year	0.0305	Central Bureau of Statistics and UNFPA, 2002, "Population of Nepal-Village Development Committee/Municipalities Population Census 2001", Kathmandu, Nepal.
Death rate	No./year	0.0108	Central Bureau of Statistics and UNFPA, 2002, "Population of Nepal-Village Development Committee/Municipalities Population Census 2001", Kathmandu, Nepal.
Immigration rate	No./year	0.0405	Central Bureau of Statistics and UNFPA, 2002, "Population of Nepal-Village Development Committee/Municipalities Population Census 2001", Kathmandu, Nepal.
Emigration rate	No./year	0.3248	Central Bureau of Statistics and UNFPA, 2002, "Population of Nepal-Village Development Committee/Municipalities Population Census 2001", Kathmandu, Nepal.
Guides and porters per trekker	No.	0.9329	Elaboration on data from Visitor Surveys in Sagarmatha National Park, Autumn 2007 and Spring 2008
Guides and porters per climber	No.	1.333	Elaboration on data from Visitor Surveys in Sagarmatha National Park, Autumn 2007 and Spring 2008

Each of the input variables described at the beginning of this section is connected with an input table in *.csv format, which are respectively indicated in Table 14.

*Table 14: Input variables and specification of connected *.csv input table for SNPBZ*

Input variable	Input table (*.csv format)
RATES (including RATES of BIRTH, DEATH, IMMIGRATION, EMIGRATION)	*demography_rates.csv*
STAFF PER ACTIVITY	*staff_activity.csv*
SETTLEMENT POPULATION (initial value)	*settlement_population.csv*

A brief description of each input table is provided here below:

Demography_rates.csv

The data *demography_rates.csv* input table contains information concerning the rates of birth, immigration, death and emigration. For the SNPBZ case study, these data were derived from the Central Bureau of Statistics (CBS, 2002)[1].

1 CBS, 2002. *Population of Nepal-Village Development Committee/Municipalities Population Census 2001*, Central Bureau of Statistics (CBS), Kathmandu, Nepal

The input data table is composed of four rates as shown in Table 15.

Table 15: Example of input data popultaion.csv table for SNPBZ

	Rates
Birth rate	0.0305
Immigration rate	0.0405
Death rate	0.0108
Emigration rate	0.03248

Staff_activity.csv

The *staff_activity.csv* input table contains the data regarding the number of staff needed by each category of tourist (activity) during the trek. For the case study of SNPBZ, the required data were obtained through the data derived from the Visitor Surveys in Sagarmatha National Park, Autumn 2007 and Spring 2008.

The activity.csv is composed of two columns concerning:

- *Activity* [name]
- *Staff per activity* [No.]

Table 16: Example of input staff_activity.csv table for SNPBZ

Activity	Staff per activity
climbing	1.333257
trekking	0.932927

Settlement_population.csv

The settlement_population.csv table contains the initial value of local population that is used as starting value of the model. For the case study of SNPBZ, these data were gathered through the report of the project executing partner CESVI (Cooperazione e Sviluppo), an Italian organization, on different kinds of data sources listed below:

- DNPWC - Department of National Parks and Wildlife Conservation, 2006, *"Initial Environmental Examination Report On Sagarmatha National Park Management and Tourism Plan (2006 – 2011)"- IEE Report,* TRPAP Kathmandu, Nepal.
- WWF, 2006, Tables on local population made available to the HKKH Partnership Project.
- Central Bureau of Statistics and UNFPA, 2002, *"Population of Nepal-Village Development Committee/ Municipalities Population Census 2001"*, Kathmandu, Nepal.
- Interviews with Mr. Tenzing Tashi Sherpa (former Chairman, Buffer Zone, Khumjung VDC), Mr. Pemba Gyalzing Sherpa (Namche Buffer Zone Committee member) and Mr. Nima Tenzing Sherpa (Chaurikarka Buffer Zone Committee member).

The input table is composed of two columns respectively indicating:

- *Settlement* [Name]: one line for each settlement considered;
- *Initial value* [No]: initial number of local population per settlement.

Table 17: Example of input data settlement_population.csv table for SNPBZ

Settlement [Name]	*Initial Value [No.]*
Chukung	0
Dole	20
Dingboche	89
Dzonglha	20
Gokyo	20
Gorakshep	20
Khumjung	712
…	…

7.5 Management levers

There is no management lever applied to this model.

7.6 The model outputs

Indicator of performance

The main output of the Population Dynamics model is the model "performance indicator" namely NUMBER OF LOCAL POPULATION (*Tot_Pop*) that indicates the daily number of local population (including settlement population and guides and porters) present in each selected settlements of the study area. This output of the model constitutes an important input for the other models. It is calculated as the sum of no. of people per day in each settlement (*Pop*) and no. of guides and porters per day in each settlement (*G_P*) by the following equation:

$$Tot\_Pop = Pop + G\_P$$

Other outputs

Besides the performance indicator, the user can obtain other important information regarding the following intermediate variables that constitute other output of the population dynamics model:

- ✓ SETTLEMENT POPULATION (Intermediate variables)
- ✓ All the output above can be exported as a table composed of one line row per day and the following columns for the SNPBZ:

Table 18: Output variables of the population dynamics model

Output variable	Index 1	Description
Settlement population	Chukung	Number of settlement population each day in Chukung
	Dole	Number of settlement population each day in Dole
	…	…
Number of local population	Chukung	Number of local population each day in Chukung
	Dole	Number of local population each day in Dole
	…	…

7.7 Bibliography

Caroli, P., and D. Panzeri. 2007. *Porters' Survey in Sagarmatha National Park*. Preliminary analysis result. HKKH Partnership Project. Working papers.

Caroli, P.and D. Panzeri. 2008. *Migration Dynamics in Sagarmatha National Park*. Highlighting terms and features. HKKH working papers.

Sherpa. L.N., 2006. *Sagarmatha National Park Management and Tourism Plan 2006-2011*. Department of National Parks and Wildlife Conservation (DNPWC), Sagarmatha National Park, Namche, solukhumbu.

Solid Waste Management

8.1 Why was this model developed?

Sustainable management of solid waste in protected areas is of high importance due to the vulnerability of ecosystems and natural resources like surface waters and underground aquifers, landscape and biodiversity. Furthermore, the deterioration of natural resources may affect the economy of those countries in which protected areas are located and tourism is the most important economic sector. In addition, tourism development leads to great seasonal variations in quality and quantity of solid waste production. These aspects as well as the relatively high transportation costs due to the remoteness of protected areas in high mountains indicate the need of a special approach towards safe and sustainable solid waste management.

In order to support decision makers in developing appropriate waste management plans and improve the current waste management system in protected areas, the issue of environmentally sustainable management of solid waste has been addressed and a model on solid waste has been developed. Particularly, the model has been implemented as a case study of the Sagarmatha National Park and Buffer Zone (SNPBZ) where a rise in the number of tourists is increasing the level of waste production. The current waste management system in the park does not guarantee an optimal disposal. If the problem is not resolved immediately, it will exacerbate environmental pollution and lead to the reduction of the flow of tourists in the park.

The overall aim of the solid waste model is to analyse the current solid waste management in selected protected areas where the disposal and management of solid waste is of great concern (as in the SNPBZ) and contribute towards improving the current management system for better environmental sustainability.

In particular, this model is conceived and aimed to:

- categorise different type of wastes (plastic, glass, metal, other);
- quantify the waste generation;
- evaluate the existing management system and identify the current management practices of waste disposal (e.g., recycling, burying, burning, etc.);
- suggest new management practises and environmentally sustainable strategies for effective solid waste management in order to mitigate its impacts on humans and the ecosystem.

8.2 What is the context in which the model was developed?

Introduction

As reported in the SNPBZ Management Plan 2004 – 2008 (DNPWC, 2003), solid waste deposit in SNPBZ has become an issue of global concern and is considered the most prominent environmental concern to both local inhabitants as well as tourists in the area. The major contributor of solid waste in SNPBZ is found to be tourists. Tourists, in general, produce five times more waste than local inhabitants. Solid waste deposits in the Everest base camp, along the trekking routes and in settlement areas, primarily due to high influx of tourists and expeditions, increasing number of hotel/lodges and ineffective management have led to serious waste management problems in the SNPBZ.

In SNPBZ, solid waste mainly comprises of plastics, metals (cans), glasses and kitchen wastes. All bio-degradable kitchen wastes are being used to feed cattle or used for composting and hence it does not contribute to the waste management cycle. However, there is no system set in place to manage (for instance, recycle) plastics, glasses and metals and that is a major concern to solid waste management in SNPBZ.

The Sagarmatha Pollution Control Committee (SPCC), a non-profit local NGO, is a pioneer organisation actively involved in the management and regulation of solid waste pollution in SNPBZ. However, due to limited technical knowledge, effective social mobilisation and lack of financial resources, SPCC has its own limitations in providing high level of satisfactory solid waste management. Furthermore, in spite of SPCC's continuous efforts to minimise the impact of tourism on the environment, the huge influx of tourists has increased each year causing direct and indirect impacts on the environment. In 2002-2003, SPCC disposed 230,000 kg of garbage from the region, with 115,000 kg from Namche VDC and 115,000 kg from Lukla to Jorselle (23% disposable and 77% non-disposable).

Burnable garbage collected at Lukla (Pharak) region is burnt in the Himalayan Adventure Trust of Japan (HAT-J)-donated incinerator and other non-burnable and disposable garbage is buried in a suitable place. Cans and bottles are flown to Kathmandu for recycling and re-use. In many locations, through local contribution and participation, SPCC has dug rubbish pits that are large enough to dump garbage for two years, but that are, arguably, unsustainable. Local people have developed an attitude that garbage management issue is the responsibility of SPCC.

Due to the lack of effective social mobilisation and active participation by locals, waste management has not been as effective as anticipated. However, currently, local youth clubs such as Namche Youth Group and Pangboche Youth Club are mobilising waste management and clean-up campaigns (DNPWC, 2003).

Scientific evaluation and input is deemed necessary for more effective and comprehensive waste management in the area. If the solid waste produced in SNPBZ is not being managed properly, soon it may pose very serious negative impacts on its environment and tourism industry.

Qualitative analysis of the Solid Waste Model

Under the HKKH Partnership Project, the overall modeling process for the qualitative analysis of the socio-ecological system was adopted through existing studies, expert knowledge and stakeholders (Salerno *et al.*, 2009). In this context, a qualitative model on solid waste in the SNPBZ has been developed to describe and analyse current solid waste management in the park. The conceptual diagram is shown in Figure 3.

The quantity of solid waste produced in each selected settlement within the SNPBZ is dependant on the number of both local population and tourists in the settlements and the daily mass of solid waste they produce (*kg of waste type per tourist per day* and *kg of waste type per local per day)*. Waste is distinguished by four main types: plastic, metal, glass and other. Once the amount of waste produced is known, the total amount of solid waste disposed by different practices of disposal (i.e., reusing, burning, burying, transporting, recycling, incinerating) can be derived and this value represents an indicator of performance of this model. However, the amount of waste disposed by these different methods may vary. For instance, an increase in the efficiency of the burning and incinerating methods determines the amount of waste burned and incinerated.

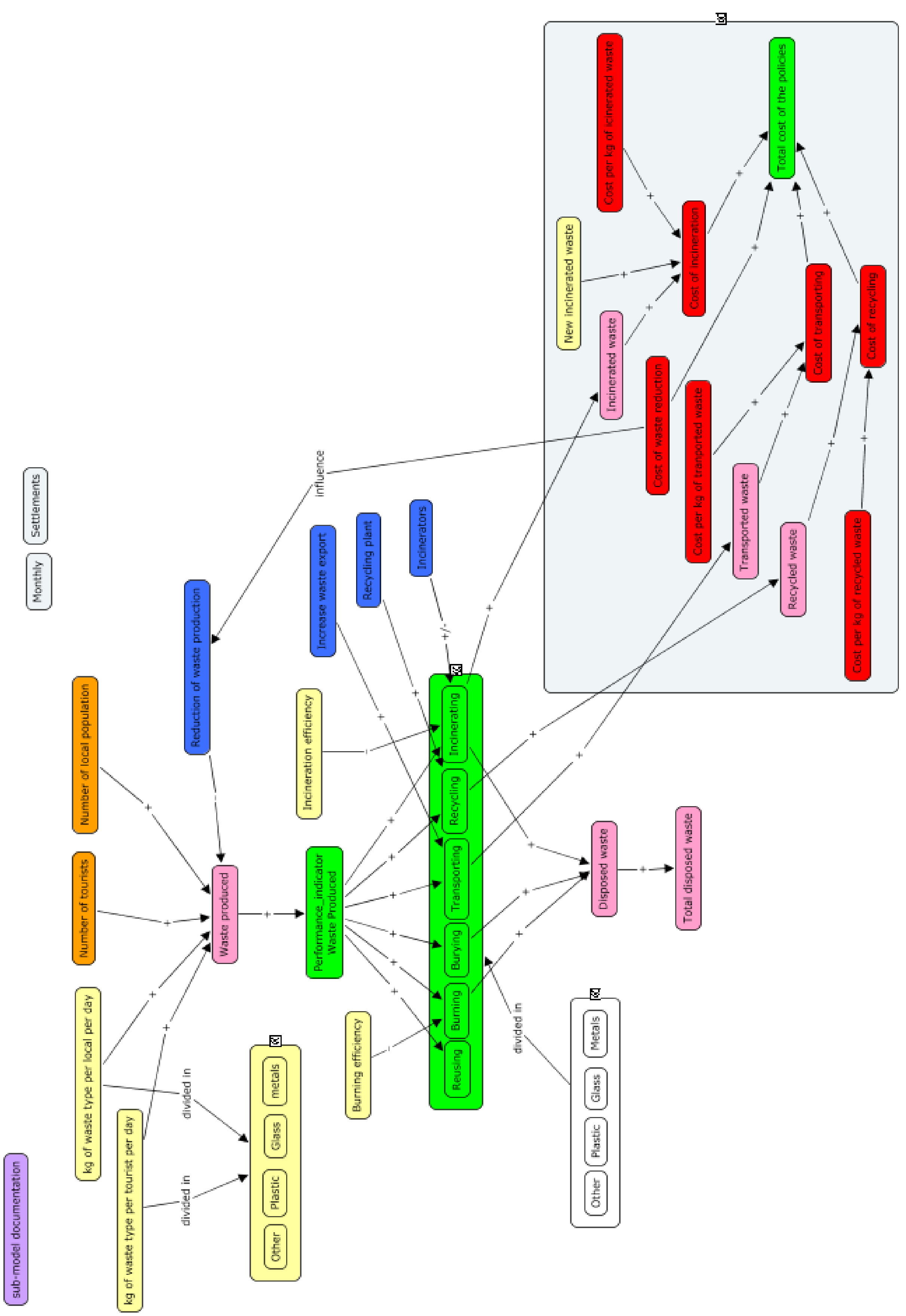


Figure 3: Qualitative diagram of the solid waste model

Management policies aimed at reducing the waste production is vital in reducing the waste produced (*Reduction of waste production*). Introduction of management policies addressed, for instance, to increase waste export, developing recycling plants especially for plastics, and building incinerators may influence the amount of waste disposed by transporting, recycling and incinerating.

The conceptual diagram in Figure 3 (at bottom-right) illustrates the economical aspects involved in implementing the management policies foreseen in the sub-model.

8.3 How does this model work?

This model calculates the amount of total solid waste produced monthly by each of the 18 settlements in SNPBZ as presented in the Tourism section. The waste produced depends on the number of tourists entering the park, including visitors, porters and guides (calculated through the Tourism flow model) and the local population (derived from the Population dynamics model). The total amount of four different types of waste (plastic, metal, glass, other) produced is calculated by applying a coefficient of production.

Through a collection efficiency index, the solid waste management model calculates the amount of waste that has been collected and littered on the ground (not collected). Then, the collected waste is disposed in six different disposal treatments (i.e., reusing, burning, burying, transporting outside, incinerating and recycling). The main management policies applied to this model has addressed the concerns regarding the reduction of waste production, the increase of the waste collection efficiency as well as the waste distribution per different disposal methods.

The costs involved in implementing different management policy levers applied in the model are also analysed.

8.4 The model inputs

The solid waste model includes four kinds of input data or input variables that are associated with an input table in *.csv file format as indicated in the Table 19.

Table 19: Input variables and correlated input table.csv files of the solid waste model.

Input variable/s	Input table (*.csv format)
Kg of waste type per local per MonTH Kg of waste type per tourist per MoNTH burning efficiency INCINERATION EFFICIENCY COLLECTION EFFICIENCY	waste_type data.csv
Disposal method: PLASTIC METAL GLASS OTHER	disposal_methods.csv
cost per Kg of transported waste cost per Kg of recycled waste cost per Kg of waste not produced cost per Kg of waste collected	cost for solid waste. csv

A brief description of each input table is provided below. An example of each table is also furnished with input data specification for the SNPBZ case study that was received from the extensive field survey. However, users can provide their own input files for the area of study simply by editing (or replacing) the current files.

Waste_type data.csv

The *waste_type data.csv* input table concerns disposal methods distribution. The table is composed of seven columns indicating input data:

Table 20: Example of waste_type data.csv input table for SNPBZ

Settlement name	Waste type	Monthly_ waste local	Monthly_ waste_ tourist	Burning efficiency	Incineration efficiency	Collection efficiency	
Chukung	other	0	0	0.75	1	90	
Chukung	plastic	0	0	0.75	1	90	
Chukung	glass	0	0	0	0	90	
Chukung	metal	0	0	0	0	90	
Dole	other	7.908	5.142	0.75	1	90	
Dole	plastic	0.327	0.6	0.75	1	90	
Dole	glass	0	0	0	0	90	
Dole	metal	0.021	0	0	0	90	
Dingboche	other	10.134	6.6	0.75	1	90	
Dingboche	plastic	0.735	0.54	0.75	1	90	
...	...	...	...	...	...	…	
...	...	...	...	...	...	…	

Disposal_methods.csv

The *disposal_methods.csv* input table indicates the monthly percentage of each waste type (glass, metal, plastic, other) disposed by different disposal methods (indicated by an appropriate index as described hereafter) for each settlement.

The table is composed of six columns indicating:

- *Settlement name* [Name]
- *Disposal method* [Name]
- *Disposal method other* [%]
- *Disposal method plastic* [%]
- *Disposal method glass* [%]
- *Disposal method metal* [%]

Table 21: Example of disposal_methods.csv input table for SNPBZ

Settlement name	Disposal method [Name]	Disposal method other [%]	Disposal method plastic [%]	Disposal method glass [%]	Disposal method metal [%]
Chukung	reusing	0	0	0	0
Chukung	burning	0	0	0	0
Chukung	burying	0	0	0	0
Chukung	transporting	0	0	0	0
Chukung	incinerating	0	0	0	0
Chukung	recycling	0	0	0	0
Dole	reusing	86	10	5	0
Dole	burning	14	50	0	0
Dole	burying	0	40	95	100
Dole	transporting	0	0	0	0
Dole	incinerating	0	0	0	0
Dole	recycling	0	0	0	0
Dingboche	reusing	86	10	5	0
Dingboche	burning	13	50	0	0
Dingboche	burying	1	40	95	100
Dingboche	transporting	0	0	0	0
...	...	...	...	...	...
...	...	...	...	...	...

Cost for solid waste.csv

The *cost for solid waste.csv* input table is composed of four columns indicating the costs per Kg respectively of:

- *transported waste* [NRs]
- *recycled waste* [NRs]
- *waste not produced* [NRs]
- *waste collected* [NRs]

Table 22: Example of cost per solid waste.csv input table for SNPBZ

Cost per Kg of transported waste [NRs]	Cost per Kg of recycled waste [NRs]	Cost per Kg of waste not produced [NRs]	Cost per Kg of waste collected [NRs]
50	300	50	50

For the SNPBZ, all costs are expressed in Nepalese Rupee (NRs). The user can change both the units and values.

8.5 Management levers

The management levers applied in this model are designed to:

1. reduce the initial quantity of waste products (REDUCTION OF WASTE PRODUCTION);

2. change the values of DISPOSAL METHODS DISTRIBUTION AND POLICY LEVERS to describe the distribution percentage of different waste types (i.e., PLASTIC, METALS, GLASS, OTHER) by different methods of waste disposal (REUSING, BURNING, BURYING, TRANSPORTING OUTSIDE, INCINERATING, RECYCLING). This policy allows assigning percentage of different waste types to different disposal methods as conceptually shown in Table 6 and by means of an input matrix structure as shown in Table 2. The cells contain percentages indicating the percentage of total waste of a type disposed by the respective method. When the percentage changes in a cell, the sum of the values of the line must be equal to 100%. Thus the user can choose a particular disposal method and the implied policy lever, for instance, by changing percentage of values in favour of reusing, incinerating (the management policy is in favour of introducing a new incinerator for burning plastic, papers and other burnable matters), transporting (that means encourage transporting waste products outside of SNPBZ) and recycling, especially for plastic which is the most polluting waste (by introduction of recycling plant for plastic). The repartition percentage of different waste types for each method of waste treatment is described on Table 23.

Table 23: Cconceptual indication of repartition percentage of different waste type (rows) for each method of waste disposal treatment (columns). The cells contain percentages indicating the percentage of total solid waste of each type disposed by each method. When the percentage changes in a cell, the sum of the values of the line must be equal to 100%.

	Reusing	Burning	Burying	Transporting	Incinerating	Recycling	Σ
Plastic	10 %	50 %	40 %	0 %	0 %	0 %	100 %
Glass	5 %	0 %	95 %	0 %	0 %	0 %	100 %
Metal	0 %	0 %	100 %	0 %	0 %	0 %	100 %
Other	86 %	14 %	0 %	0 %	0 %	0 %	100 %

3. change the values of COLLECTION EFFICIENCY to describe the percentage of waste that is properly collected. The difference of percentage indicates that the waste not collected, hence neither segregated nor disposed, but assumed to be littered on the ground in the park.

The management policies included in the model are summarised on Table 24.

Table 24: Management levers for the solid waste model, including specifications and connected variables

Policy Lever Name	Specification	Variable/s name	Unit and Description
Policy lever_Reduction of waste production	This value denotes the percentage of reduction of kilograms of waste type produced.	Reduction	[0,100], int [%]
Policy lever_Disposal methods distribution and policy levers	This policy lever represents the actual "solid waste management scheme" and gives an indication of waste segregation efficiency. It represents the assignment of waste of different types (, plastics, metal, glass, other) to different disposal methods by a matrix with disposal methods in columns (Reusing, burning, burying, transporting outside, incinerating and recycling) and waste types (plastic, metal, glass, others) in rows. The cells contain percentages indicating the percentage of total waste of a type disposed by the respective method. This implies the existence of a specific method (if there is no facility for recycling, the respective cell would show a value 0) but also the ability to assign waste deliberately to a specific method (segregation efficiency): a value 0 in cell "recycling" could also mean that there is a facility for recycling but the waste management scheme is not able to segregate the waste meant to be recycled.	Plastic Metal Glass Other	[0,100],,int, [%] Matrix with % values. The matrix is edited outside of Simile (a macro ensures that the sums do not exceed 100% (normalisation) before it is used by the model.
Policy lever_ Collection efficiency	This policy represents the waste efficiency collection. It is a %-value describing the percentage of total waste that is collected and hence properly segregated and disposed.	Collection efficiency	[0,100] int, [%]

A brief assessment of the policy levers for the SNPBZ case study is provided in the following sections.

Management lever "Reduction of waste production"

The concerned types and amount of waste in the SNPBZ include plastic and glass, mineral water bottles, bags and rappers. All these non-biodegradable waste should be reduced, reused or recycled for effective management. However, these are simply dumped and/or burned in pits in SNPBZ, which is not a scientifically sound way of handling these types of waste.

The reduction of waste production is the best option for managing solid waste. The major types of waste production that can be reduced are plastic, glass and metals. Plastic can be reduced by substituting it with paper/ cotton materials. Similarly, glass and metals can be replaced by aluminum can like beer can. Beer bottles are banned now in SNPBZ and they have been replaced by beer cans. The number of plastic mineral water bottles can be reduced by installing more water purification devices, which has already been installed in this region to improve the quality of drinking water at the source. If more water purifiers are to be installed, the past concerns of the mineral water industries regarding local inhabitants should be taken into account. The current focus of the water purifier initiative is mainly for tourists only. Cost effectiveness and suitable adaptable technologies that will be useful even for local inhabitants need to be accessed. Other ways to reduce solid waste is by putting a ban on such items as plastic, glass and metal, or by charging certain fees for bringing these items into the park, which will discourage people from doing so.

By applying stringent regulatory measures to reduce the production of waste materials in all the settlements within SNPBZ, the environment of the park will be sustained and both tourists and local inhabitants will be encouraged to participate in its development.

Management lever "Disposal methods distribution and policy levers"

The status of waste segregation in SNPBZ is very poor. Waste segregation means to separate waste based on its types such as kitchen waste, plastic, paper, glass and metal. At present only kitchen waste is separated from other types of waste in SNPBZ. This practice may be due to the traditional practice of the inhabitants of using kitchen waste to feed cattle or composting. The SPCC is segregating waste only at the burning site and only in major settlements, but in other sites, the waste products are completely mixed up. Mainly metals and glasses are being separated from other wastes like paper, plastic, clothes and the rest is incinerated.

Inadequate segregation has caused difficulties in proper waste management in SNPBZ and dump sites are filled with mixed wastes consisting of metals and batteries. There is a very good scope of waste segregation in SNPBZ. The locals are very conscious about their environment and hence, if proper awareness and demonstrations are provided to them, they can handle the situation very effectively.

Waste segregation should be conducted at the household level so that treatment can be performed effectively. The waste should be segregated into different categories as per the composition (mainly plastic, metal, glass and others including batteries, hospital waste, etc.) at the collection site. Then, proper disposal method among a number of methods like, reusing, burning, burying and so on should be selected and used.

Management lever "Collection efficiency"

Currently, collection of solid waste in the SNPBZ is operated by SPCC staff from households, trails and mountaineering groups. SPCC is collecting waste particularly at Lukla and Namche by door-to- door visits. In other settlements, SPCC is covering the financial costs of digging pits where local people dump their waste. The SPCC also regularly collects wastes from trash bins placed in different locations of the trails. The waste collected from mountaineering groups is burned or dumped in Namche.

Such collection techniques are effective to some extent; however, with the increasing influx of tourists in the region more waste is being generated and current waste collection system of SPCC needs to be improved. Particularly, frequency of waste collection in other settlements is not sufficiently adequate and human resources and equipments are still rather scarce.

8.6 The model outputs

The model provides different outputs that include both the model performance indicators as well as other intermediate variables described hereafter. By operating on the management levers of the model, users can evaluate their effects on those outputs and obtain possible scenarios on the solid waste condition in the area.

Indicators of performance

This model provides as main output the performance indicators described hereafter. All these outputs can be exported as a table composed of records for each month and columns as reported by each different output.

- ✓ WASTE PRODUCED_1: represents actual production of waste in kilograms before further processing.

Table 25: Output table of the WASTE PRODUCED_1 performance indicator

Output variable	Index 1 (Settlement)	Index 2 (Waste type)	Description
MONTH			Simulation month
waste produced_1 [Kg]	Chukung	other	Amount of other waste produced in the Chukung considering the reduction policy lever.
		plastic	Amount of plastic produced in the Chukung considering the reduction policy lever.
		metal	Amount of metal produced in the Chukung considering the reduction policy lever.
		glass	Amount of glass produced in the Chukung considering the reduction policy lever.
	…	…	…
	...	...	...

- ✓ TOTAL AMOUNT OF WASTE DISPOSED BY DIFFERENT METHODS: represents the repartition percentage of four different waste types for each method of waste disposal (all categories in kg) and includes the following performance indicators:

  - REUSING: this variable indicates the total waste reused [Kg];
  - BURYING: this variable indicates the total waste buried [Kg];
  - BURNING: this variable indicates the total waste burned [Kg];
  - TRANSPORTING: this variable indicates the total waste transported outside [Kg];
  - INCINERATING: this variable indicates the total waste incinerated [Kg];
  - RECYCLING: this variable indicates the total waste recycled [Kg];

  A table as the one reported below (Table 26) is required for each performance indicator or output variable (by type of disposal methods), but for simplicity, here we provide an example just for REUSING

Table 26: Output table of the REUSING performance indicator

Output variable	Index 1 (Settlement)	Index 2 (Waste type)	Description
MONTH			Simulation month
REUSING [Kg]	Chukung	other	Amount of other waste reused in Chukung
		plastic	Amount of plastic reused in Chukung
		metal	Amount of metal reused in Chukung
		glass	Amount of glass reused in Chukung
	...	...	...
	...	...	...

✓ LITTERED WASTE: represents actual amount of waste in kilograms that is neither segregated nor disposed, but assumed to be littered on the ground in the park.

Table 27: Output table of the LITTERED WASTE performance indicator

Output variable	Index 1 (Settlement)	Index 2 (Waste type)	Description
MONTH			Simulation month
LITTERED WASTE [Kg]	Chukung	other	Amount of other waste littered on the soil in the Chukung
		plastic	Amount of plastic littered on the soil in the Chukung
		metal	Amount of glass littered on the soil in the Chukung
		glass	Amount of metal littered on the soil in the Chukung
	...	...	...
	...	...	...

✓ TOTAL COSTS OF THE POLICIES: represents the total costs connected to the management levers of the model, including costs from incineration, recycling processes, transporting activity, reduction of waste production and waste collection.

Table 28: Output table of TOTAL COSTS OF THE POLICIES performance indicator

Output variable	Index1 Settlement)	Description
MONTH		Simulation month
total costs of the policies [Kg]	Chukung	Total costs of the policies in the Chukung
	Dole	Total costs of the policies in the Dole
	Dingboche	Total costs of the policies in the Dingboche
	...	…
	....	Total costs of the policies in the settlement_...

Other outputs

Other outputs of the model include the following intermediate variables:

- ✓ WASTE PRODUCED_0: this variable calculates daily amount in Kilograms of waste produced in each selected settlement together by local population and tourists, without considering the policy lever of reducing the amount of waste produced.
- ✓ DISPOSED WASTE: identifies a state variable representing the total amount in Kilograms of disposed waste (i.e., the sum of buried, burned and incinerated waste) by waste type.
- ✓ TOTAL DISPOSED WASTE: represents the total amount in Kilograms of waste disposed without waste type distinction.

These outputs (intermediate variables), like the performance indicators, can be exported as a table composed of records for each day and includes columns as reported here below by each different output.

Table 29: Output table of the WASTE PRODUCED_0 intermediate variable

Output variable	Index 1 (Settlement)	Index 2 (Waste type)	Description
MONTH			Simulation month
waste produced_0 [Kg]	Chukung	other	Amount of waste type - other produced in the Chukung
		plastic	Amount of waste type 2 produced in the Chukung
		metal	Amount of waste type ... produced in the Chukung
		glass	Amount of waste type 1 produced in the Chukung
	...	...	...
	...	...	...

Table 30: Output table of the DISPOSED WASTE intermediate variable

Output variable	Index 1 (Settlement)	Index 2 (Waste type)	Description
MONTH			Simulation month
disposed waste [Kg]	Chukung	other	Amount of other waste type disposed in the Chukung
		plastic	Amount of plastic disposed in the Chukung
		metal	Amount of metal disposed in the Chukung
		glass	Amount of glass disposed in the Chukung
	...	...	...
	...	...	...

Table 31: Output table of the TOTAL DISPOSED WASTE intermediate variable

Output variable	Index 1 (Settlement)	Description
MONTH		Simulation month
total disposed waste [Kg]	Chukung	Total amount of waste disposed in the Chukung
	Dole	Total amount of waste disposed in the Dole
	Dingboche	Total amount of waste disposed in the Dingboche
	...	Total amount of waste disposed in the settlement_...
	....	Total amount of waste disposed in the settlement_...

8.7 Bibliography

APO. 2001. *Hazardous Waste Management Policies and Practices in Asian countries.* Asian Productivity Organization, Japan.

CEE, 1999. *The energy assessment study of Sagarmatha National Park and Chaurikharka VDC (Pharak) Area*, WWF Nepal Program, Kathmandu.

DNPWC, 2003, *Sagarmatha National Park and Buffer Zone: Management Plan 2004-2008*. Department of National Parks and Wildlife Conservation (DNPWC), Babar Mahal, Kathmandu.

HKKH Partnership Project. 2007. *Mission Report* to Sagarmatha National Park (March 2007). Institutional Consolidation for the Coordinated and Integrated Monitoring of Natural Resources towards Sustainable Development and Environmental Conservation in the Hindu Kush-Karakoram-Himalaya Mountain Complex.

Kaczala, F. 2007. *Technologies for Solid and Wastewater Treatment, Energy from Waste, Remediation of Contaminated Sites, and Emissions Related to Climate.* Proceedings 1 and 2 of the 6th International Conference on “Technologies for Solid and Wastewater Treatment, Energy from Waste, Remediation of Contaminated Sites, and Emissions Related to Climate”, University of Kalmar, Sweden.

Protocol Activities (2007-2008) between Kathmandu University (KU) and Ev-K2-CNR Committee (Ev-K2-CNR) for researches supporting the development of a decision support system in the Hindu Kush-Karakoram-Himalaya Mountain Complex (HKKH Partnership Project), July 2007.

Tripathi P.R. and R. Gurdeep, 1989. *Solid Waste Pollution*, First edition.

TRPAP/UNDP. 2006. *Tourism Resources Mapping Profile, Solukhumbu District.* Ministry of Culture and Civil Aviation, UNDP, TRPAP, Nep/99/013.

Energy Management Model

9.1 Why was this model developed?

Sustainable energy management in protected areas is of high importance especially in areas where fuelwood is still a major source of energy. The deterioration of natural resources due to forest extraction may affect the economy of those countries in which protected areas are located and tourism is the most important economic sector. In addition, tourism development leads to great seasonal variations in quality and quantity of solid waste production. These aspects as well as the relatively high transportation costs due to the isolated nature of the areas, especially in the remote protected areas of mountain regions indicates the need of a special approach towards sustainability of energy management.

In order to support decision makers in developing an appropriate energy management plan and improve the energy management system in these protected areas, the issue of environmentally sustainable management of energy has been addressed and this model has been developed. Particularly, the model has been implemented for the case study of the Sagarmatha National Park and Buffer Zone (SNPBZ) where the rise in the number of tourists is placing an increasing demand of energy. The current energy management system in the park does not guarantee an optimal supply of the energy.

The overall objective of the energy management model is to analyse the energy scenario[1] of protected areas in order to develop an effective and appropriate energy management system that aims at balancing energy demand with an appropriate energy supply in a sustainable manner for better protection of natural resources, including suggestions for expansion and development of alternative energy resources.

In particular, this model is conceived and aimed to:

- identify the current energy consumption pattern and future demand in the studied area;
- study the availability of non-conventional energy sources such as hydro, solar, wind, and biomass to replace/retrofit the use of conventional energy source viz., firewood, dung, LPG, kerosene, diesel, etc.;
- apply the best practice architectural design to reduce energy demands and to maximise the use of energy-efficient utilities;
- suggest new management practices and environmentally sound strategies to comply with the increasing demand of energy while mitigating relevant impacts on the ecosystem;
- suggest the need for awareness and capacity building activities in the energy management;
- estimate the total costs for accomplishing the envisaged policy levers in order to assess their feasibility in economic terms.

1 Scenarios are intended here as hypothetical situations that provide insights about the changes affecting the system if specific management levers would be put in place.

The model allows the assessment of different energy scenarios in order to:

1. discover and explore current and future energy consumption patterns and figure out energy demand situation;
2. assess options and potentials regarding substitution of conventional energy sources based on possible developments in the availability and potential of non-conventional energy sources;
3. evaluate options to reduce overall energy demand by improving insulation of buildings (best and most appropriate practices) and promoting use of energy-efficient utilities; discover the most effective awareness-raising and capacity-building activities that facilitate the improvement of energy management.

The model has been implemented and developed for the case study of SNPBZ in Nepal, where fuelwood has been identified as the major source of energy for majority of people but is not produced adequately to meet the increasing demands of tourists and the local population in the area. This model can perform an analysis of the current energy scenario of the SNPBZ and develop an appropriate environmental and management plan, including suggestions for alternative energy resources.

9.2 What is the context in which the model was developed?

Introduction

The energy supply of SNPBZ is overwhelmingly dependent on traditional biomass sources of fire wood, fuels, agricultural residues and animal wastes. Fuelwood is the major source of energy for the majority of people in SNPBZ. Similarly, the increasing population and tourism activities in the area have led to a rise in fuelwood demand, particularly for heating and cooking (DNPWC, 2003), thus applying pressure on accessible forests. However, forests and shrub lands of SNPBZ cannot produce adequate wood to meet increasing demands of tourists and local population. Currently, large amounts of fuelwood and livestock dungs are used to fuel metal space heating stoves locally known as "buwa" in many tourist lodges. Fuelwood is still the main source of energy for cooking in traditional and semi-modern lodges and restaurants.

Despite increasing trend in demand of alternative energy, it is still minimally developed and so pressure on accessible forests for meeting household energy demands may continue in this area of SNPBZ.

Fuelwood consumption in SNPBZ and the probable increasing demands of tourists and local population in the coming years point out the necessity of a suitable and sustainable energy management plan that includes promotion of alternative energy technologies in order to satisfy increasing demand for energy and ensure the sustainable use of natural resources while minimising human impact on the fragile ecosystem of the park. A rational use of forest products and new energy alternatives can guarantee the conservation of the park's natural resources.

Various energy alternatives to fuelwood such as electricity, solar energy, kerosene and LPG have been recently introduced to SNPBZ. Electric grids were introduced to some of the settlements of Namche and Khumjung and this has largely contributed to reducing firewood usage in major settlements. But in Chaurikharka, only a few individual and community peltric sets mainly for lighting purposes only have been set up, generating limited electricity, (Household Survey, 2002). Solar home systems are used widely in the area, but it is used only for lighting purposes and only a few hotels use solar water heating system. Likewise, kerosene and liquefied petroleum gas (LPG) are not affordable means of alternative energy for a majority of the residents. Because it is relatively accessible and affordable, fuelwood is still the major source of energy for most residents of SNPBZ.

The SNPBZ Management Plan 2004 - 2008 (DNPWC, 2003) and SNP Management and Tourism Plan 2006-2011 (Sherpa, 2002) have envisaged and supported several strategies to reduce fuelwood demands and consumption by gradually phasing out wood-based space heaters from all tourist lodges and private homes in the SNPBZ. Generally, development and use of multiple energy options are encouraged giving priority to renewable and environmentally sound options such as hydropower and forestry. The construction of energy-efficient building design by insulating and passive solar heating is required and hydro-electric projects large enough to support communities in cooking and heating with electricity are also encouraged.

In keeping with the framework of the HKKH Partnership Project, this model primarily incorporates data obtained from extensive and strategic field data collected from 2007 to 2008 at SNPBZ and some from secondary data sources, mainly literature reviews of some already existing data.

Qualitative analysis of the Energy Management Model

The first step in the overall modeling process adopted under the HKKH Partnership Project has been the qualitative analysis of the socio-ecological system of SNPBZ on the basis of existing studies, expert knowledge and stakeholders (Salerno *et al.*, 2009). In the framework of the HKKH Partnership Project, during the overall modelling process, the energy situation in SNPBZ has been identified as a key management issue through qualitative analysis of the socio-ecosystem conducted along with local and national stakeholders as well as experts.

In this context, a qualitative model on energy management in the SNPBZ (Figure 4) was developed to analyse the current energy scenario in the park. The conceptual diagram, shown in Figure 4, describes the *energy demand* and *energy supply* in the studied area in each selected settlement (18 settlements are considered for the SNPBZ). The *electric energy balance* and the related *total costs* for the accomplishment of the specific management levers envisaged in the model can be assessed by running the model.

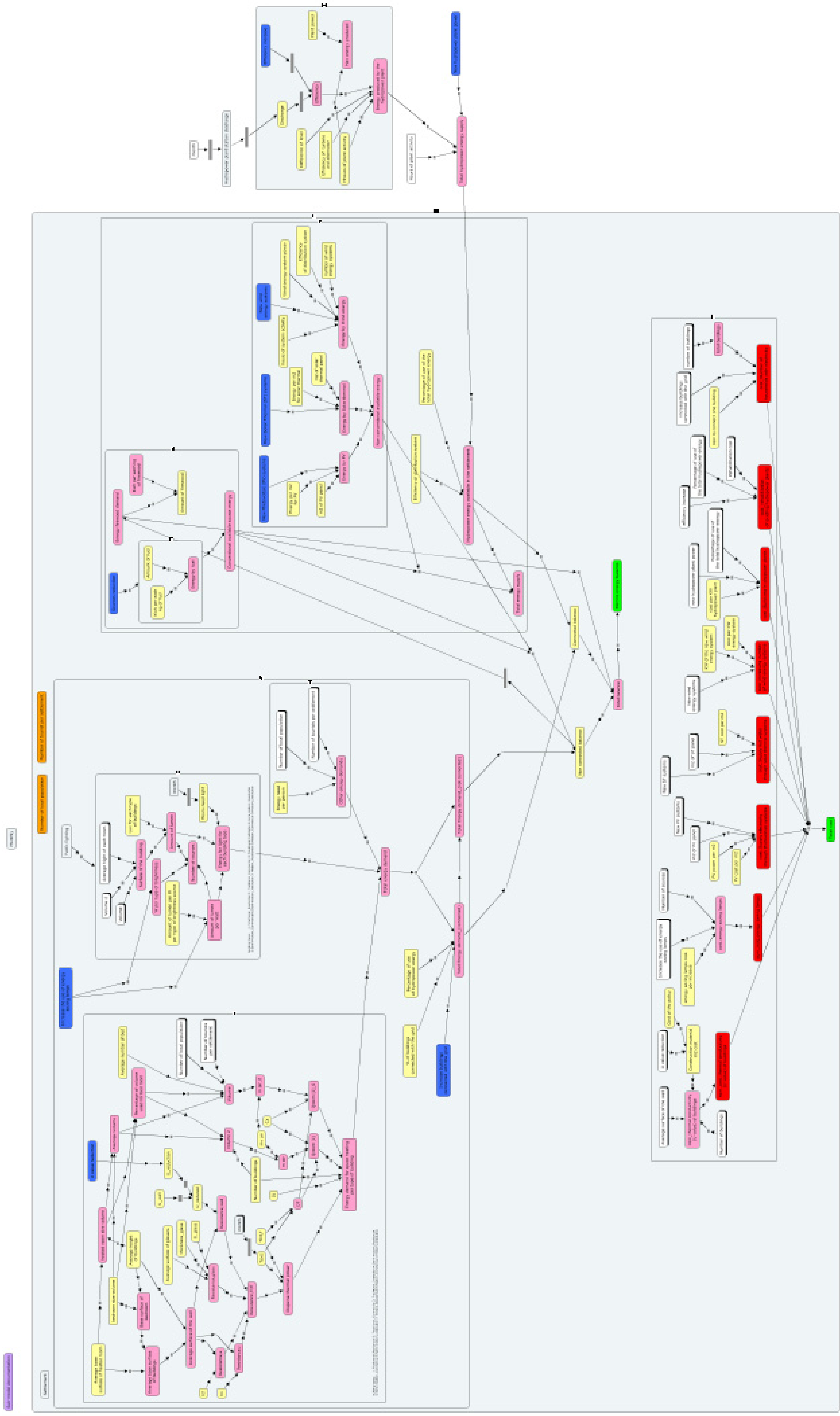


Figure 4: Qualitative diagram of the energy management model

Each compartment of the conceptual diagram is described below in detail.

The total *energy demand* shown in Figure 4 is conceptually due to the total energy used for space heating and lighting as well as the for other activities, particularly for pumping, heat water, entertainment, cooking and utilities, indicated as *for other purposes* under *energy demand*.

The total *energy demand for space heating* (Figure 5) is directly proportional to the building typology, and several variables including the surface and volume of the heated room, the characteristics of walls and glass windows (thickness, average surface, resistance, etc.) of the building, the difference between internal and external temperature that influences the heat required, the disperse thermal power of the building and the number of buildings. The total energy required for heating the buildings is also proportional to the local population and tourists in the park. The data on local population and tourists are input data coming from the Tourism and Population Dynamics sub-models.

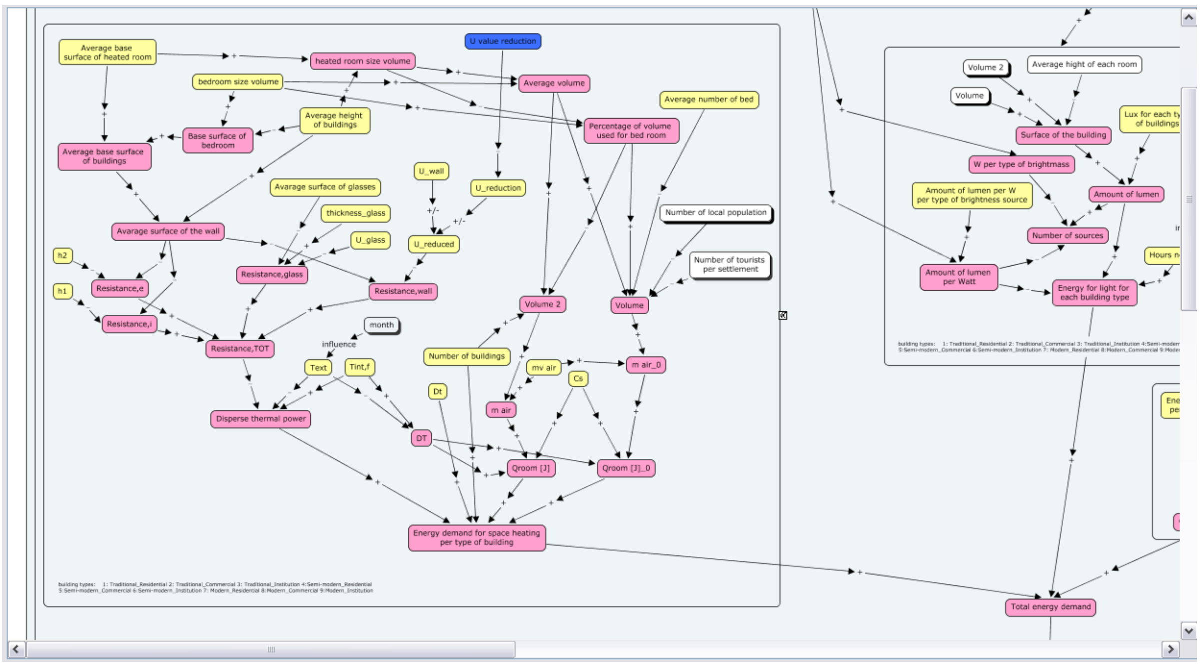


Figure 5: Qualitative concept regarding the energy demand for space heating per building type

The total *energy demand for lighting* (Figure 6) per building type is relative, in particular, to the hours of lighting that vary monthly, the amount of lumen in relation with the lux for each building, the surface of the building and the amount of lumen per watt.

Other energy demands (Figure 6) is in regards to the energy required for pumping, heating water, cooking and utilities and entertainment. For each type of such activities, the energy demand is proportional to the both the local population and number of tourists per each settlement, and the *energy need per person*.

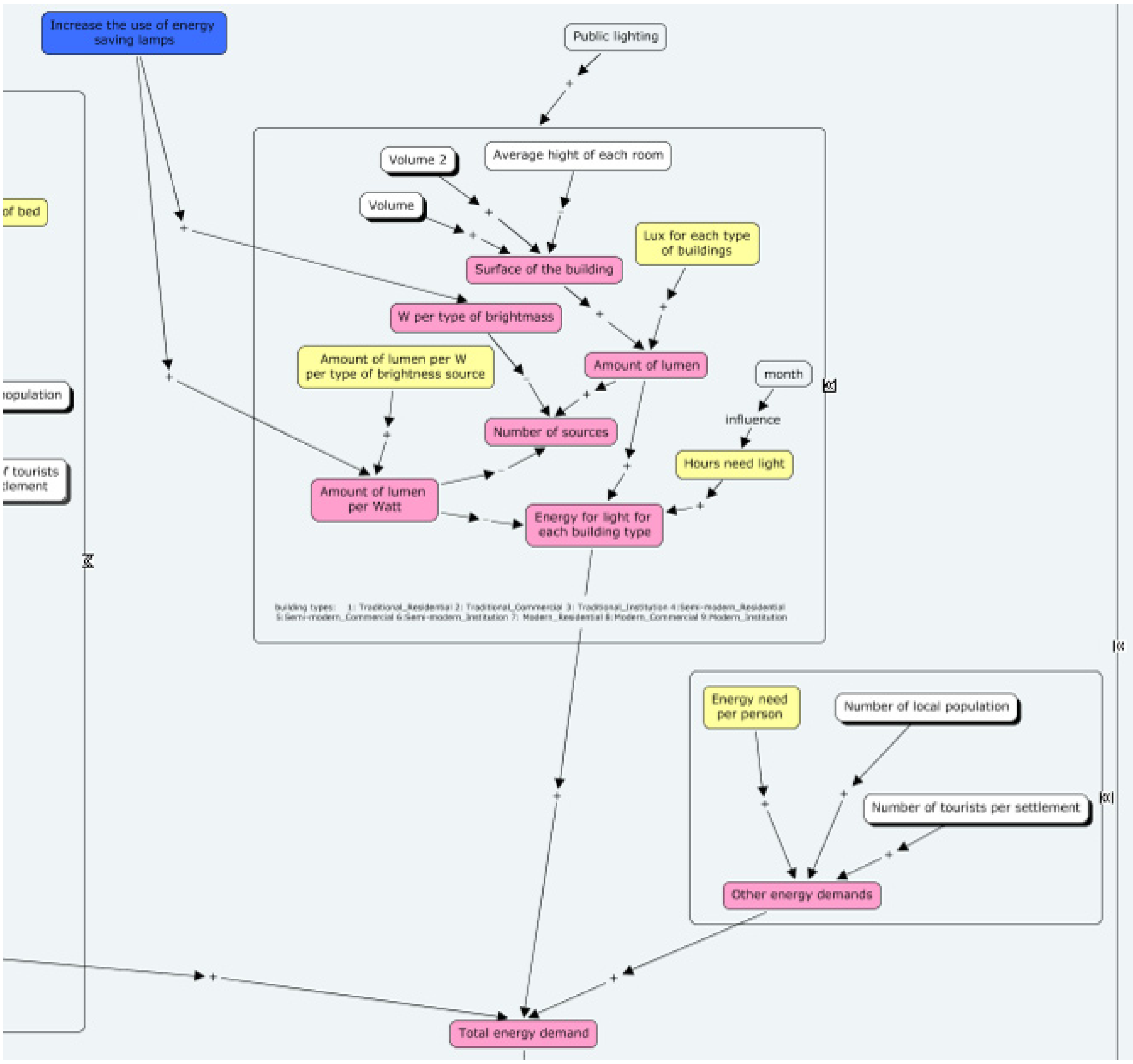


Figure 6: Qualitative concepts regarding the energy demand for lighting per building type and other activities (i.e., pumping, heating water, cooking and utilities, entertainment)

The *total energy supply*, as shown in the concept diagram (Figure 7), is proportional to both the *conventional energy sources*, which is represented by both firewood and fuels (i.e., kerosene, LPG, dung) and the *non-conventional energy sources*, which is supplied by alternative energy sources like photovoltaic (PV), solar thermal (ST) and wind energy (WE), hydropower systems.

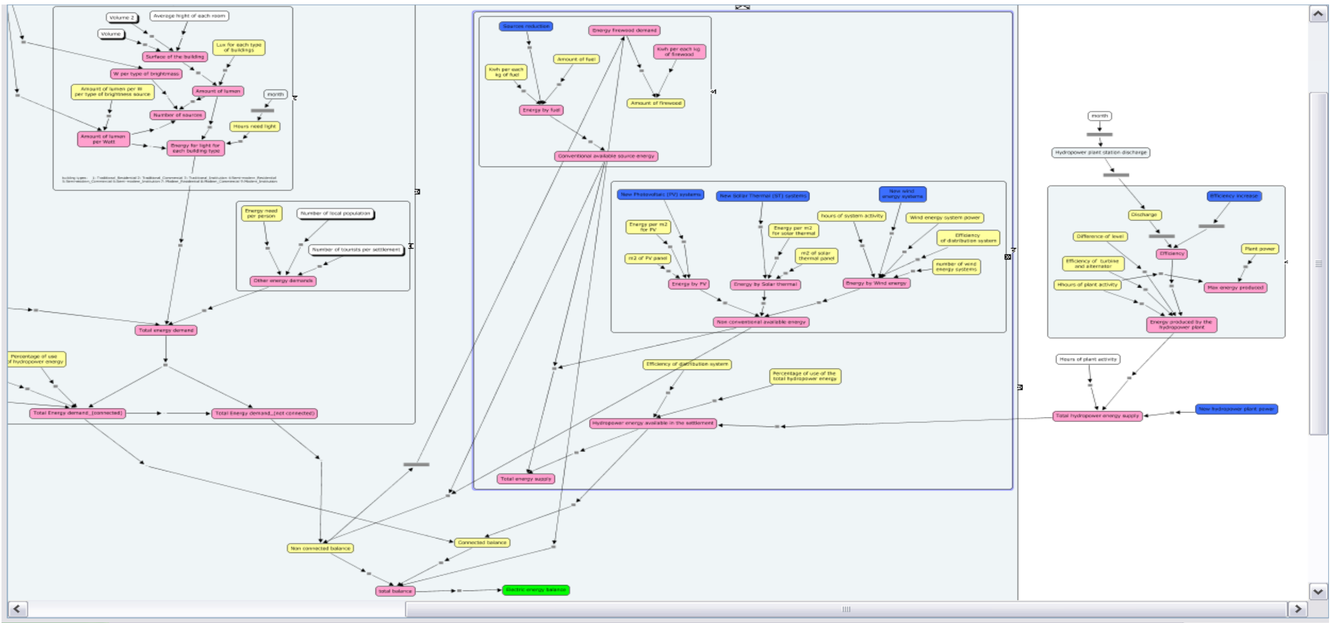


Figure 7: Qualitative diagram regarding the energy supply (concepts in the middle) from conventional and non-conventional energy sources

Conventional energy sources are derived from the *energy supply by fuels* that is proportional to the *Amount of fuel* used and the kilowatt hour (kWh) per each kilogram (kg) of fuel. It is also influenced by the management policy of reducing conventional energy sources (*sources reduction*). Conventional energy supply is also given by firewood and the a*mount of firewood* used is proportional to the *energy demand of firewood* and the *kWh per each kg of firewood*. On one hand, the *energy demand for firewood* is influenced by the calculated energy balance for buildings that are not connected with the electricity grid (non connected energy balance), and on the other hand, it is in proportional to the total energy balance, which increases if the energy demand for firewood increases as well.

The *non-conventional energy source* is represented by the alternative energy sources available in the park. In particular, the *energy by photovoltaic* (PV) *systems* is dependent on the surface of PV panel and the energy per m2 and on the policy lever to establish new PV systems. The *energy by solar thermal* (ST) *systems* depends on the surface of ST panel and the energy per m2 and on the policy lever to create new ST systems as energy sources. Finally, the *energy by wind energy (WE) systems* is proportional to the number of wind energy systems, the energy power, the efficiency of distribution, the hours of activity of the system and increase if the policy lever to establish new wind energy systems is accomplished.

The *total energy supply* (Figure 7) is also proportional to the *hydropower energy available in the settlements*, which depends on the *total hydropower energy supply*, the *percentage of use of the total hydropower energy* and its *efficiency of distributio*n. The *total hydropower energy supply* (Figure 8) is derived by the energy produced by both existing hydropower plants and possible new ones foreseen by the policy lever. However, at present, there are six existing hydropower plant stations in the park (Bom Kola Lukla, Ghatte Kola MHP Phakding, Khumbu Bijuli Company Thame, Tangboche MHP, Pangboche MHP, Phortse MHP). Therefore, the calculation of the total hydropower energy supply is not per settlement, but refers to the existing hydropower plant stations cited above. The rivers from where electricity generated, have different monthly discharge depending on the seasonality and thus, efficiency of the hydropower depends also on them, which can, however, be increased as per the policy lever.

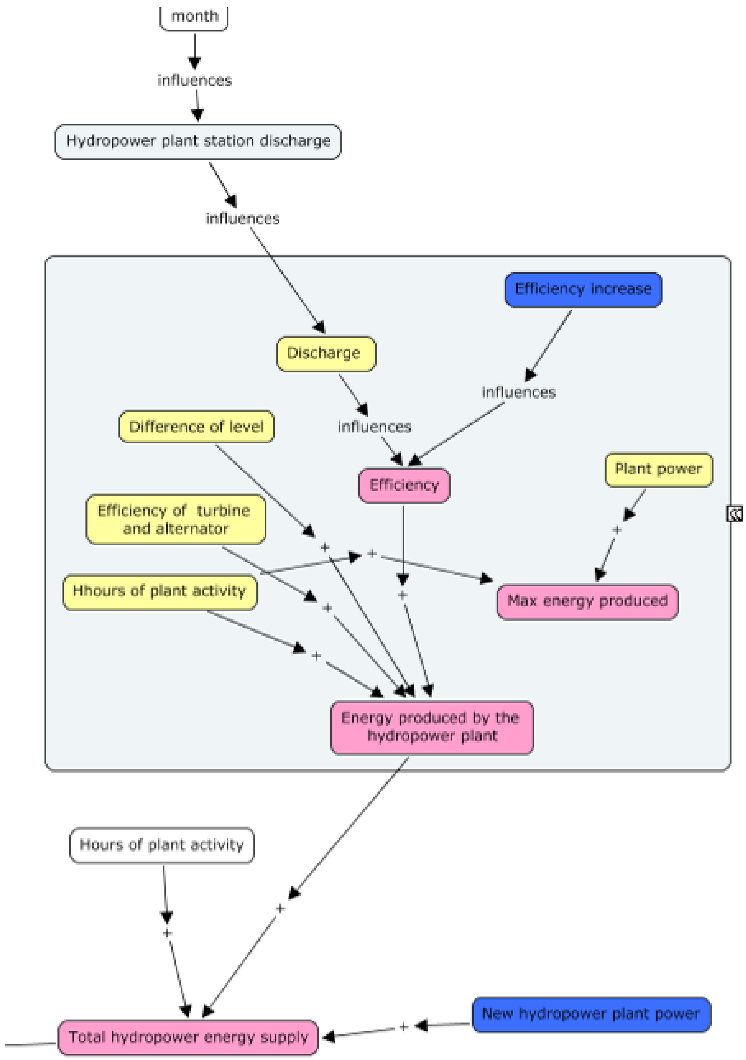


Figure 8: Concept diagram regarding the contribution of existing hydropower plant to the total hydropower energy supply, which is proportional to the hours of plant activity and the construction of new hydropower plant power as per the related policy lever

Since some buildings are connected with the electric grid, the total energy demand may be distinguished in terms of *total energy demand_connected* (energy demand from buildings that are connected to the grid and also utilise electricity) and *total energy demand_not connected* (for buildings not connected to the grid and cannot utilise electricity). However, since not all total energy demand of buildings connected with the electricity grid is supplied by the grid itself, the *total balance* is evaluated by the *connected balance*, which is proportional to both the *total energy demand_connected* and the *hydropower energy available in the settlement*. The non connected balance is proportional to the *total energy demand_ not connected* and both the *conventional* and *non conventional energy available*. The *non connected balance* influences the energy demand for firewood, since wood is the main source of energy used to supply the energy demand for buildings that are not connected with the electricity grid.

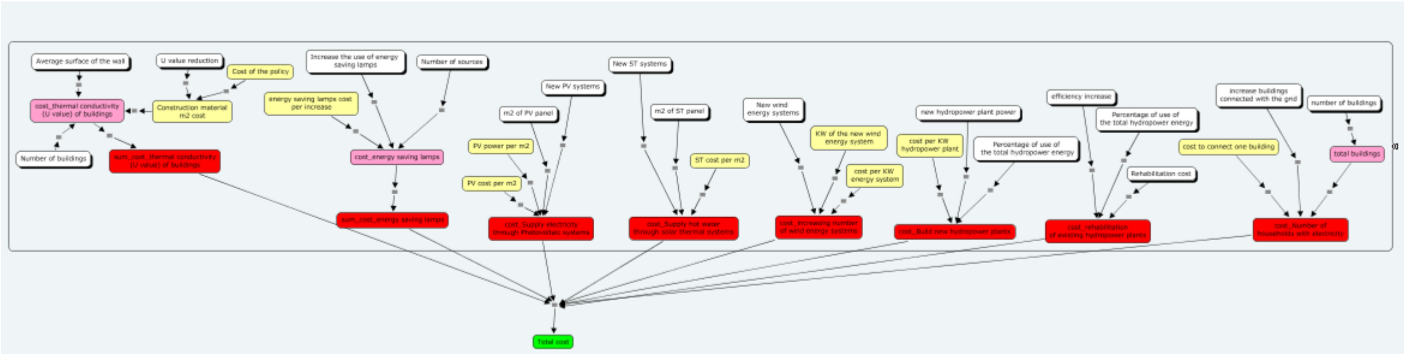


Figure 9: Concept diagram regarding the costs of all the policy levers considered in the sub-model. The indicator of performance of the policies is represented by the total costs

9.3 How does this model work?

In order to interpret the model outputs in a meaningful way, it is essential to have a basic understanding of how this model works and its dynamics.

On the most general level, energy management model simulates (calculates) the balance between ENERGY DEMAND and ENERGY SUPPLY for 18 selected settlements in SNPBZ based on the management options and settings that are selected by the user, in monthly time steps. Energy demand and consumption depends on type of building, and the user may consider nine different types of buildings in the model.

The TOTAL ENERGY DEMAND as calculated by this model accounts for energy used by households in the selected settlement(s) for specific daily tasks, such as heating and lighting or other purposes (including cooking, pumping, entertainment, production of hot water, etc.). Regarding the energy demands, the model distinguishes between energy supplied from the electricity grid (hydropower energy) and energy generated by other means through conventional energy sources (combustion of fuels biomass and fuelwood) and alternative energy systems (photovoltaic (PV) panels, solar thermal (ST) system, wind energy (WE) hydropower systems).

The ENERGY SUPPLY is calculated in this model separately for the following main energy types:

1. CONVENTIONAL ENERGY sources: firewood and fuels in general, including kerosene, LPG and animal wastes (dung for the case study of SNPBZ) that are imported or locally collected/produced;
2. ALTERNATIVE or NON-CONVENTIONAL ENERGY sources: PV systems, ST systems (ST), wind energy systems;
3. HYDROPOWER ENERGY available: electric energy provided by existing hydropower plants.

The management policies applied to this model can be grouped into three types based on their effects: reduction of energy consumption, increasing energy efficiency and increasing the use of non-conventional renewable energy sources. These management policies will be described later in the management lever section.

The costs for different management policy levers applied in the model will also be analysed.

9.4 The model inputs

Nine kinds of input data or input variables are considered in the energy management model and are associated with an input table in *.csv format as indicated in the Table 32:

Table 32: Input variables and correlated input table .csv files of the energy management model

Input variable/s	Input table (*.csv format)
Amount of fuel kwh for each Kg of fuel	data_energy_amount of fuel.csv
AMOUNT OF INDIGENOUS FUELs (dung & fuelwood)	data_energy_amount of indigenous fuel.csv
U_vALUE BY BUILDING TYPE	data_energy_buildingtype.csv
Difference of level efficiency of turbine and alternator plant power rehabilitation cost efficiency increase	data_energy_hydropower station.csv
Energy per m2 for photovoltaic panels Energy per m2 for solar thermal Hour of system activity m2 of PV panel m2 of ST panel pERCENTAGE USE OF CONNECTED ENERGY Percentage of use of the total hydropower energy Power produced by wind system Number of wind energy system Natural dispersion	data_energy_settlement.csv
average base surface of heated room average height of buildings average number of beds average surface of glass bedroom size volume hours need light number of buildings % of people in each building type % of tourists in each building type Lux for each type of buildings Lumen/W	data_energy_settlement_x_building type.csv
Energy need per person by ENERGY TYPE	data_energy_settlement_x_energy.csv
Discharge data	discharge.csv
External temperature	Text.csv

A brief description of each input table is provided below. An example of each table is also furnished with input data specifics for the SNPBZ case study. However, users can provide their own input files for the area of study simply by editing (or replacing) the current files.

Data_energy_amount of fuel.csv

The *data_energy_amount of fuel.csv* input table deals with different types of fuels and energy that were produced when combusted.

The table is composed of eight columns indicating:

- *Settlement* [Name]
- *Settlement index* [No]
- *Fuel type* [Name]: type of fuel used as energy source (kerosene, LPG, dung)
- *Fuel type index* [No.]: a number that identifies each type of fuel considered
- *Amount of fuel* [kg/month]: amount of fuel per fuel type used in each settlement
- *kWh for each Kg of fuel* [kWh/Kg]: energy produced by the combustion of a kilogram of each fuel type in each settlement;
- *Cost of fuels* [NRs/Kg]

Table 33: Example of data_energy_amount of fuel.csv input table for SNPBZ

Settlement	Settlement index	Fuel Type	Fuel Type index	Amount of fuel [kg/month]	kWh for each Kg of fuel [kWh/Kg]	Cost of fuels [NRs/Kg]
Chukung	1	Kerosene	1	510	12.94	127.8
Chukung	1	LPG	2	117	13.66	246.5
Dole	2	Kerosene	1	1029	12.94	127.8
Dole	2	LPG	2	30	13.66	246.5
Dingboche	3	Kerosene	1	4725.6	12.94	127.8
Dingboche	3	LPG	2	389.4	13.66	246.5
Dzonglha	4	Kerosene	1	0	12.94	127.8
Dzonglha	4	LPG	2	0	13.66	246.5
Gokyo	5	Kerosene	1	2346.3	12.94	127.8
Gokyo	5	LPG	2	297	13.66	246.5
Gorakshep	6	Kerosene	1	882	12.94	127.8
Gorakshep	6	LPG	2	216	13.66	246.5
Khumjung	7	Kerosene	1	2937.6	12.94	127.8
Khumjung	7	LPG	2	702.54	13.66	246.5
Lobuche	8	Kerosene	1	1470	12.94	127.8
Lobuche	8	LPG	2	358.8	13.66	246.5
Lukla	9	Kerosene	1	1653.96	12.94	127.8
Lukla	9	LPG	2	2500.5	13.66	246.5
Machherma	10	Kerosene	1	844.2	12.94	127.8
Machherma	10	LPG	2	234	13.66	246.5
Marlung	11	Kerosene	1	0	12.94	127.8
Marlung	11	LPG	2	0	13.66	246.5
...	...	...	...	...	...	...

Data_energy_amount of indigenous fuel.csv

The *data_energy_amount of indigenous fuel.csv* input table is composed of eight columns indicating:

- *Settlement* [Name]
- *Settlement index* [No]
- *Fuel type* [Name]: type of fuel used as energy source (kerosene, LPG, dung)
- *Fuel type index* [No.]: a number that identifies each type of fuel considered
- *kWh for each Kg of fuel* [kWh/Kg]: energy produced by the combustion of a kilogram of indigenous fuel type (i.e. dung) in each settlement
- *Percentage of dung used in each settlement [%]*
- Energy from fuelwood [kWh]: energy from fuelwood in each settlement

Table 34: Example of data_energy_amount of indigenous fuel.csv input table for SNPBZ

Settlement	Settlement index	Fuel Type	Fuel Type index	kWh for each Kg of fuel	Percentage of dung used in each settlement	Energy from fuelwood
Chukung	1	Dung	3	3.02	0	0
Dole	2	Dung	3	3.02	6.01	3843
Dingboche	3	Dung	3	3.02	9.79	15570
Dzonglha	4	Dung	3	3.02	0	0
Gokyo	5	Dung	3	3.02	6.63	1890
...	...	...	...	...	...	...

Data_energy_building type.csv

The *data_energy_building type.csv* input table is composed of two columns indicating:

- *Building type* [Name]
- *U value* [W/m^2*K]: average U value[2] of the wall for each type of buildings

Table 35: Example of data_energy_building type.csv input table for SNPBZ

Building_type	U_value
residential_traditional	0.3
residential_semimodern	0.68
residential_modern	0.21
commercial_traditional	0.68
commercial_semimodern	0.63
commercial_modern	0.54
institutional_traditional	0.87
institutional_semimodern	0.87
institutional_modern	0.87

2 U_value represents the thermal conductivity of building components (walls, floors, ceilings, doors and windows).

Data_energy_hydropower station.csv

The *data_energy_hydropower station.csv* input table deals with the hydropower energy system. The table is composed of six columns indicating respectively:

- *Settlement plant name* [Name]: settlement where the hydropower plan is located
- *Difference of level [m]:* difference of level getting/present on each hydropower station
- *efficiency of turbine and alternator* [No. between 0 and 1]: average efficiency of turbine and alternator of each hydropower station
- *plant power* [KW]: plant power of each hydropower station
- *rehabilitation cost* [currency]]: average rehabilitation cost of each hydropower station (for SNPBZ costs are expressed in Nepalese Rupees, NRs)
- *efficiency increase* [0 or 1]: policy levers regarding the possibility of increasing the efficiency of turbine and alternator of each hydropower station.

Table 36: Example of data_energy_hydropower station.csv input table for SNPBZ

Settlements Plant Name	Difference of level (m)	efficiency of turbine and alternator	plant power	rehabilitation cost	efficiency increase
Lukla Bom Khola	201	0.75	100	9919330	0
Phakding Ghatte Khola MHP	128	0.75	70	7310395	0
Thame Khumbu Bijuli Company	216	0.7	630	1.1E+08	0
Tyanboche Tyanboche MHP	92.5	0.5	22	1764819	0
Pangboche Pangboche MHP	66	0.5	15	965233.2	0
Phortse Phortse MHP	135	0.5	60	2959027	0

Data_energy_settlement.csv

The *data_energy_settlement.csv* input table contains data on the different sources of energy in each settlement, including hydropower, photovoltaic (PV), solar thermal (ST), wind energy (WE) hydropower systems and also natural dispersion data.

The table is composed of eleven columns indicating respectively:

- *Settlement* [Name]
- *Settlement index* [No]
- *Monthly Energy per m2 for photovoltaic panels* [kWh/m^2]: average amount of energy produced by a m2 of photovoltaic panel in each settlement
- *Monthly Energy per m2 for solar thermal* [kWh/m^2]: average amount of energy produced by a m2 of solar thermal panel in each settlement
- *Hour of system activity* [h/month]: average number of hours of activity of each wind energy system in each settlement
- *m2 of PV panel* [m^2]: average photovoltaic panel surface in each settlement
- *m2 of ST panel* [m^2]: average solar thermal panel surface in each settlement
- *Percentage of use of connected energy* [%]: percentage on the total amount of energy connected in each settlement coming from hydropower energy
- *Percentage of use of the total hydropower energy* [%]: percentage on the total hydropower energy produced used in each settlement
- *Power produced by wind system* [KW]: average wind energy system power in each settlement

Table 37: Example of data_energy_settlement.csv input table for SNPBZ

Settlement	Settlement index	Monthly Energy per m2 of photovoltaic panels	Monthly Energy per m2 of thermal panels	Hour of wind system activity (h/month)	m2 of PV	m2 of ST	Percentage use of hydropower energy	Percentage use of total hydropower energy	Power produced by wind system	Number of wind energy system	Natural dispersion
Chukung	1	108	183.12	120	0	0	1.5	0	0.3	0	5.1
Dole	2	176.7	183.12	120	5	0	2.5	0	0.3	0	20.3
Dingboche	3	182.4	183.12	120	17.55	0	3.1	0	0.3	0	3.5
Dzonglha	4	164.05	183.12	120	0	0	0	0	0.3	0	0
Gokyo	5	190.5	183.12	120	2.46	0	0.9	0	0.3	0	9
Gorakshep	6	187.8	183.12	120	2.55	0	1.9	0	0.3	0	4.4
Khumjung	7	164.05	210.6	120	0	14	13.2	23.8	0.3	0	0.6
Lobuche	8	185.7	150	120	2.68	6	1.3	0	0.1	1	10
Lukla	9	131.1	174.9	120	3.15	41	3.9	4.6	0.3	0	2.3
Machherma	10	178.2	183.12	120	4.44	0	4.5	0	0.3	1	2.1
Marlung	11	164.05	183.12	120	0	0	0	0	0.3	0	0
Namche	12	155.4	207.3	120	0.68	31	11.4	38.4	0.3	0	5.1
Pangboche	13	164.05	183.12	120	0	0	12.6	7.3	0.3	0	6.8
Phakding	14	129.6	172.8	120	0.88	8	2.6	6.6	0.3	0	9.7
Pheriche	15	182.7	183.12	120	9.06	0	2.3	0	0.5	1	6.2
Phortse	16	160.5	183.12	120	1.47	0	6.3	9.8	0.3	0	11.2
Tengboche	17	160.5	183.12	120	0	0	7.3	1.6	0.3	0	6.4
Thame	18	160.5	183.12	120	0	0	3.8	7.9	0.3	0	6.5

Data_energy_settlement_x_building type.csv

The *data_energy_settlement_x_building type.csv* is composed of fourteen columns indicating respectively:

- *Settlement* [Name]
- *Settlement index* [No]
- *Building type* [Name]
- *average base surface of heated room* [m^2]: average base surface of heated rooms for each building type in each settlement
- *average height of buildings* [m]: average height of each building type in each settlement
- *average number of beds* [No.]: average number of beds in each building type of each settlement
- *average surface of glass* [m^2]: average surface of glasses of each building type in each settlement
- *bedroom volume* [m^3]: average volume of bedroom of each building type in each settlement;
- *hours need light* [h/month]: average number of hours of each building type in each settlement in which people need artificial light
- *number of buildings* [No.]: average number of buildings for each building type in each settlement
- *% of people in each building type* [%]
- % of tourists in each building type [%]
- Lux for each type of buildings
- Lumen/W

Table 38: Example of data_energy_settlement_x_building type.csv input table for SNPBZ

Settlement	Settlement index	Building type	average base surface of heated room	average height of buildings	average number of beds	average surface of glass	bedroom volume	hours need light	number of buildings	% of people in each building type	% of tourists in each building type	Lux for each type of buildings	Lumen/W
Chukung	1	residential_traditional	58.83	2.23	2	4.62	0	150	2	80	0	80	40
Chukung	1	residential_semimodern	24.23333	2.23	3	7.76	0	150	0	0	0	80	40
Chukung	1	residential_modern	41.96	2.23	4	5.14	0	150	0	20	0	80	40
Chukung	1	commercial_traditional	38.32714	2.23	23	3.99	0	90	0	0	40	100	40
Chukung	1	commercial_semimodern	81.33	2.26	26	3.99	0	90	4	0	0	100	40
Chukung	1	commercial_modern	29.655	2.23	50	3.99	0	90	0	0	60	100	40
Chukung	1	institutional_traditional	81.45333	2.23	1	6.69	0	200	0	0	0	200	40
Chukung	1	institutional_semimodern	81.45333	2.23	1	6.69	0	200	0	0	0	200	40
Chukung	1	institutional_modern	81.45333	2.23	1	6.69	0	200	0	0	0	200	40
Dole	2	residential_traditional	58.83	2.23	2	4.62	0	150	3	80	0	145	10
Dole	2	residential_semimodern	24.23333	2.23	3	7.76	0	150	2	0	0	145	10
Dole	2	residential_modern	41.96	2.23	4	5.14	0	150	0	20	0	145	10
Dole	2	commercial_traditional	38.32714	2.23	23	2.26	0	90	0	0	40	180	10
Dole	2	commercial_semimodern	48.96	2.23	20	2.26	24.15	90	5	0	0	180	10
Dole	2	commercial_modern	29.655	2.23	50	2.26	0	90	0	0	60	180	10
Dole	2	institutional_traditional	81.45333	2.23	1	6.69	0	200	0	0	0	200	10
Dole	2	institutional_semimodern	81.45333	2.23	1	6.69	0	200	0	0	0	200	10
Dole	2	institutional_modern	81.45333	2.23	1	6.69	0	200	0	0	0	200	10
Dingboche	3	residential_traditional	58.83	2.23	2	4.62	0	150	20	80	0	104	14
Dingboche	3	residential_semimodern	24.23333	2.23	3	7.07	0	150	10	0	0	104	14
Dingboche	3	residential_modern	41.96	2.23	4	5.14	0	150	0	20	0	104	14
Dingboche	3	commercial_traditional	35.09	3.04	40	3.17	48	120	8	0	40	155	14
Dingboche	3	commercial_semimodern	69.52	2.02	35	9.88	32.2	120	14	0	0	155	14
Dingboche	3	commercial_modern	29.655	2.23	50	6.53	0	120	0	0	60	155	14
Dingboche	3	institutional_traditional	81.45333	2.23	1	6.69	0	200	0	0	0	200	14
Dingboche	3	institutional_semimodern	81.45333	2.23	1	6.69	0	200	0	0	0	200	14
Dingboche	3	institutional_modern	81.45333	2.23	1	6.69	0	200	0	0	0	200	14
...		...	...	...	...	...	...	...	...				

Data_energy_settlement_x_energy.csv

The *data_energy_settlement_x_energy.csv* input table is composed of six columns indicating:

- *Settlement* [Name]
- *Settlement index* [No]
- *Energy type* [Name]: type of activity for which energy is required/used
- *Energy type index [No]:* a number indicating the type of energy according to its use/destination
- *Energy need per person* [kWh/month]: average monthly amount of energy that each person needs for "energy type" in each settlement.

Table 39: Example of data_energy_settlement_x_energy.csv input table for SNPBZ

Settlement	Settlement index	Energy type	Energy type index	Energy need per person kWh/month
Chukung	1	Energy required for cooking	1	297.1031
Chukung	1	Energy used for entertainment	2	0.28
Chukung	1	Energy used to hot water	3	24.50335
Chukung	1	Energy used to pump water	4	0
Dole	2	Energy required for cooking	1	222.7889
Dole	2	Energy used for entertainment	2	0.15
Dole	2	Energy used to hot water	3	47.51679
Dole	2	Energy used to pump water	4	0
Dingboche	3	Energy required for cooking	1	780.8881
Dingboche	3	Energy used for entertainment	2	0.15
Dingboche	3	Energy used to hot water	3	25.03
Dingboche	3	Energy used to pump water	4	0
Dzonglha	4	Energy required for cooking	1	0
Dzonglha	4	Energy used for entertainment	2	0
Dzonglha	4	Energy used to hot water	3	0
Dzonglha	4	Energy used to pump water	4	0
...		...	...	...

Discharge.csv

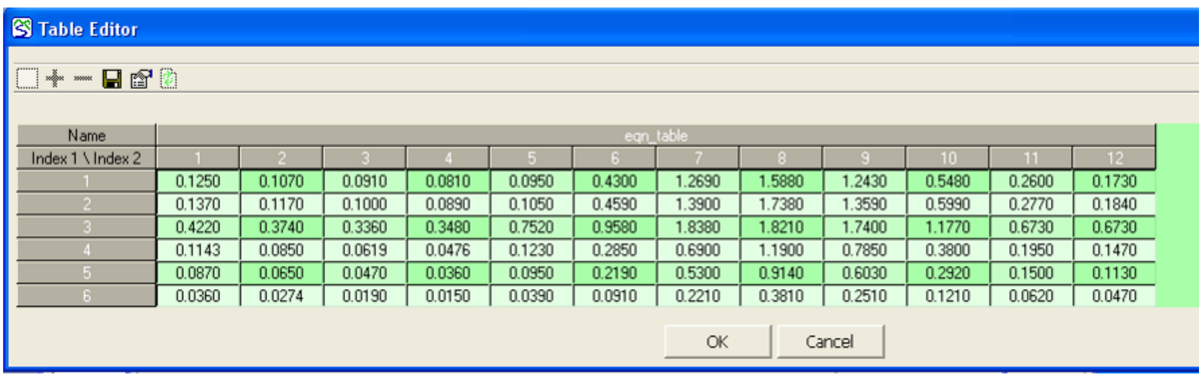
The *discharge.csv* input table contains data on the discharge (*Discharge data* [m^3/s]) that each hydropower plant intercepts in each month (month/discharge).

An example of input table for the SNPBZ case study is shown in Table 40, where six operative hydropower plants have been identified (namely Bom Khola, Lukla; Ghatte Khola MHP, Phakding; Khumbu Bijuli Company, Thame; Tyanboche MHP; Pangboche MHP; Phortse MHP). A value indicating the monthly discharge intercepted is reported for each hydropower plant per each month (indicated through the corresponding number: January=1, February=2, March=3, etc.). The user can add data for more hydropower plants as needed.

Table 40: Example of discharge.csv input table for SNPBZ

Month/ Discharge [m3/s]	Month	Lukla Bom Khola	Phakding Ghatte Khola MHP	Thame Khumbu Bijuli Company	Tyanboche MHP	Pangboche MHP	Phortse MHP
January	1	0.125	0.137	0.422	0.1143	0.087	0.036
February	2	0.107	0.117	0.374	0.085	0.065	0.0274
March	3	0.091	0.1	0.336	0.0619	0.047	0.019
April	4	0.081	0.089	0.348	0.0476	0.036	0.015
May	5	0.095	0.105	0.752	0.123	0.095	0.039
June	6	0.43	0.459	0.958	0.285	0.219	0.091
July	7	1.269	1.39	1.838	0.69	0.53	0.221
August	8	1.588	1.738	1.821	1.19	0.914	0.381
September	9	1.243	1.359	1.74	0.785	0.603	0.251
October	10	0.548	0.599	1.177	0.38	0.292	0.121
November	11	0.26	0.277	0.673	0.195	0.15	0.062
December	12	0.173	0.184	0.673	0.147	0.113	0.047

This input table has to be inserted by the user in the model as transposed matrix as shown by the following screenshot (Figure 10) from the model in Simile. Months are reported in columns and discharge data per each hydropower plant in rows, where each row corresponds to a hydropower plan (six for the SNPBZ case study).



Name	eqn_table											
Index 1 \ Index 2	1	2	3	4	5	6	7	8	9	10	11	12
1	0.1250	0.1070	0.0910	0.0810	0.0950	0.4300	1.2690	1.5880	1.2430	0.5480	0.2600	0.1730
2	0.1370	0.1170	0.1000	0.0890	0.1050	0.4590	1.3900	1.7380	1.3590	0.5990	0.2770	0.1840
3	0.4220	0.3740	0.3360	0.3480	0.7520	0.9580	1.8380	1.8210	1.7400	1.1770	0.6730	0.6730
4	0.1143	0.0850	0.0619	0.0476	0.1230	0.2850	0.6900	1.1900	0.7850	0.3800	0.1950	0.1470
5	0.0870	0.0650	0.0470	0.0360	0.0950	0.2190	0.5300	0.9140	0.6030	0.2920	0.1500	0.1130
6	0.0360	0.0274	0.0190	0.0150	0.0390	0.0910	0.2210	0.3810	0.2510	0.1210	0.0620	0.0470

Figure 10: Screenshot of the discharge.csv input table for SNPBZ. The cells report the monthly discharge [m^3/s] per each hydropower plant (six here) in each month (months are indicated with the corresponding number from 1 to 12)

Text.csv

The *Text.csv* input table is composed of columns indicating:

- *Month* [No]: a number indicating the corresponding month
- *Text* [K]: monthly external temperature in each settlement

Table 41: Example of text.csv input table for SNPBZ

Month	Chukung	**Dole**	**Dingboche**	**...**
1	265	268	267	...
2	265	269	267	...
3	268	272	270	...
4	271	275	273	...
5	273	277	276	...
6	277	281	279	...
7	278	281	280	...
8	278	282	280	...
9	276	280	278	...
10	272	276	275	...
11	270	273	272	...
12	267	270	269	...

Other inputs

The model entails some other input variables namely "variable parameters" that are connected to a minimum and a maximum value. Their value may be changed by connecting an input table or managed as a slider input[3]. Furthermore, if the user does not act with an input table or with the slider input, it is also possible to assign an initial value that the Simile software considers as real value of the variable.

The following lists the model variable parameters with the indication of their minimum and maximum values:

- *Hours of plant activity* (Minimum = 0, Maximum = 24)
- *Amount of lumen per W per type of brightness source* (Minimum = 0, Maximum = 25)
- *Tint,f* (Minimum = 285, Maximum = 298)
- *Cost per kWh hydropower plant* (Minimum = 0, Maximum = 1000000)
- *Percentage of use of the total hydropower energy* (Minimum = 0, Maximum = 100)
- *Efficiency of distribution system* (Minimum = 0, Maximum = 1)
- *kWh for each Kg of firewood* (Minimum = 2, Maximum = 8)
- *Energy per m2 for PV* (Minimum = 0, Maximum = 10000)
- *Energy per m2 for solar thermal* (Minimum = 0, Maximum = 10000)
- *Wind energy system power* (Minimum = 0, Maximum = 1000)
- *Efficiency of distribution system* (Minimum = 0, Maximum = 1)
- *Hours of system activity* (Minimum = 0, Maximum = 24)
- *m2 of PV panel* (Minimum = 0, Maximum = 1000)
- *m2 of solar thermal panel* (Minimum = 0, Maximum = 1000)
- *Number of wind energy systems* (Minimum = 0, Maximum = 100)

3 For technical specification refer to the model quantitative documentation.

9.5 Management levers

By setting or changing model input parameters that are associated with specific management levers, users can simulate different scenarios, i.e., hypothetical situations that provide insights about the changes affecting the system if specific management levers would be put into place. For the specific case of SNPBZ, the management levers were developed in collaboration with local and national stakeholders and experts to ensure that they reflect viable options for improving the management of the park area that are worthwhile to explore by means of simulating hypothetical scenarios.

The effect of the user-defined management lever settings on the system can be assessed by looking at the changes in the system's "performance indicators" over time. The performance indicators are explained in detail in the model output section.

The "Energy policies" of the main management levers applied to this model are designed to affect the following dynamics of the model:

1. **Reduction of energy consumption –** positively affecting the ENERGY BALANCE by reducing energy consumption:
   - through the increasing use of energy saving lamps (ENERGY SAVING LAMPS);
   - by reducing the loss of energy caused by inefficient insulation of buildings (U VALUE REDUCTION). In fact, buildings can be made more energy efficient by reducing heat loss through better insulation, which physically corresponds to a decrease in thermal conductivity (the U_value) of building components (walls, floors, ceilings, doors and windows);
   - by reducing the use of conventional energy types like firewood and other generic fuels (e.g., kerosene, LPG, dung) (SOURCE REDUCTION) by carrying out awareness raising activities in favour of alternative energy sources.

2. **Increase of energy efficiency** – reducing energy losses and consequently positively affecting the Energy BALANCE, particularly:
   - INCREASE EFFICIENCY (HP) by improving the electricity distribution system for energy generated by hydropower through the rehabilitation of existing hydropower plants;
   - Redistribution of hydro energy to efficiently use total hydro power energy (PERCENTAGE OF USE OF THE TOTAL HYDROPOWER ENERGY);
   - Distribution of hydro energy to use total new hydropower energy (PERCENTAGE OF USE OF THE TOTAL NEW HYDROPOWER ENERGY).

3. **Increase the use of non-conventional, renewable energy sources** by promoting alternative energy supply, by subsidising renewable energy technology:
   - NEW SOLAR THERMAL (ST) SYSTEMS: generating hot water by installing new solar thermal systems;
   - NEW PHOTOVOLTAIC (PV) SYSTEMS: generating electricity by installing and operating new photovoltaic panels;
   - NEW WIND ENERGY SYSTEMS: generate electricity by building new wind energy systems;
   - NEW HYDROPOWER PLANT POWER: increase energy supply by building new hydropower plants.

All the management policies envisaged in the model address all the energy supply and demand problems of both the local people and stakeholders and can be categorised in "Energy demand management levers" and "Energy supply management levers".

The tables in the following two sections list management levers schematically and provide information on the way values for management levers can be set. It shows the minimum and maximum value of the management lever and its type: whether it requires an integer (int) or real value (real) to be defined and unit of the lever.

Energy demand management levers

Table 42: Policy levers addressing energy demand in the energy management model, including specification and connected variables

Policy Lever Name	Brief description	Variable name	Specification	Unit and Description
Policy_lever_ thermal conductivity	If the buildings are made of materials that are not thermally insulated, a great deal of heat will be escaped aggravating the poor supply of energy sources. The energy consumption can be reduced by properly insulating the buildings.	U-value reduction (improved insulation of buildings)	This value denotes the thermal conductivity of the building per building type (weighing average of different wall areas)	[0,1], real, [No.] Value is 0 if the policy is not applied, but is 1 if reduction of thermal conductivity of buildings (lower values achieved through better insulation)
				[0,100], int, [%]
Policy_lever_energy saving lamps	Energy saving lamps produces high lumen with less energy consumption and longer life. The use of energy saving lamps such as Compact Fluorescent Lamp (CFL), White Light Emitting Diode (WLED) should be maximised. Thus people should be encouraged using CFL and WLED in order to maximise the access to electricity to other households.	increase the use of energy saving lamps	% of households substituting traditional through energy saving lamps	[0,1], int Value is 0 if the policy is not applied, but is 1 whether all households substituting traditional through energy saving lamps

Energy supply management levers

Table 43: Policy levers addressing energy supply in the energy management model, including specification and connected variables

Policy Lever Name	Brief description	Variable/s name	Specification	Unit and Description
Conventional energy/ Policy_lever_Reduce energy sources.	Reduce the use of fuelwood and fuels (including kerosene, LPG and dung). This policy concerns both commercial (imported) and indigenous energy sources.	Sources reduction	% decrease of conventional energy sources, like firewood and fuels (kerosene, LPG diesel use)	[0,1], real, [No.]
Non-conventional energy/ Policy_lever_Increase use of PV	Photovoltaic (PV) devices produce electrical power directly from light. The use of it has to be maximised in order to increase the livelihood of people away from the grid.	New PV systems	% increase of overall area of PV systems	[0,1], real, [No.]
Non-conventional energy/ Policy_lever_Increase use of ST	Solar thermal (ST) energy is a technology for harnessing solar energy for thermal energy (heat). The use of frost proof solar thermal systems should be encouraged to reduce other energy source for heating water.	New ST systems	% increase of overall area of ST systems	[0,1], real, [No.]
Non-conventional energy/ Policy_lever_New wind systems	Wind power is the conversion of wind energy into a useful form, such as electricity, using wind turbines. Use of wind power has to be encouraged to reduce the conventional energy source such as Kerosene and LPG.	New wind energy systems	% of newly installed wind energy systems	[0,10], real, [No.]
Policy_lever_Build new hydropower plants	Hydropower plants produces huge amount of electrical energy that could be advantageously used for substituting commercial and traditional sources of energy.	New hydropower plants	Power output produced by newly installed hydropower plants	[0,1000], int, [KW]

Existing hydropower plant/ Policy_lever_rehabilitation of existing hydropower plants	Maintenance of overall efficiency (system efficiency) of existing hydropower plants could be achieved through the partial or complete rehabilitation of hydropower plants. Rehabilitation is the best option to increase the energy efficiency with low price.	Efficiency increase	Efficiency-coefficient of turbine and alternator in existing hydropower plants	[0,1], int
Policy lever_redistribution of the hydroenergy	For efficient use of the hydro energy in each settlement, it is important to efficient distribution scheme. It will increase the percentage balance for efficient use of the total hydropower in the selected study area.	Percentage of use of the total hydropower energy	Percentage of use of the total hydropower energy used by each settlement	[0,100], int, [%]
Policy lever_distribution of the hydroenergy	For efficient use of the hydro energy in each settlement, it is important to efficient distribution scheme for new hydropower energy. It will increase the percentage balance for the efficient use of the total new hydropower in the selected study area.	Percentage of use of the total new hydropower energy	Percentage of use of the total new hydropower energy used by each settlement (to apply contemporary to the installation of a new hydropower)	[0,100], int, [%]

9.6 The model outputs

The model provides different outputs that include both the model performance indicators as well as other intermediate variables described hereafter. By operating on the management levers of the model, the user can evaluate their effects on those outputs and obtain possible scenarios on the energy demand and supply in the studied area.

Indicators of performance

The model outputs will tell the user the "performance of the system" based on the management lever-values selected before and after running the model. By means of interpreting values of performance indicators for a simulation, the user will obtain information about the potential positive and negative effects of the chosen management option (management lever settings). Again, the performance indicators have been developed in collaboration with local and national stakeholders and experts and reflect key system dynamics of high relevance for managers. Since the user runs the model for the settlements of interest, the following indicators show the situation for each selected settlement, not for the entire study area (in this particular case the SNPBZ).

This model provides the following three performance indicators:

- ✓ ELECTRIC ENERGY BALANCE [kWh]: represents the total balance between energy supply and energy demand in each settlement.
- ✓ TOTAL COSTS [currency]: the implementation of the management levers is associated with the respective financial costs. As in reality, the extent to which management options are put into practice has an effect on the overall budget required. In our model, this means that the cost involved in implementing a management option is dependent on the value chosen for a management lever. This indicator simply sums up the cost for all management levers as set by the user on park level. If no management action is taken – all management levers set to 0 – this indicator will be 0 and the model will run based on a "business as usual" scenario. All costs reflect the whole studied area.
- ✓ TOTAL SETTLEMENT COSTS [currency]: costs of the management policies applied on a settlement level.

For the SNPBZ, all these outputs can be exported as a table composed of records for each month and includes columns as reported per each different output.

Table 44: Output table of the ELECTRIC ENERGY BALANCE performance indicator

Name	ELECTRIC ENERGY BALANCE				
Time \ Index	Chukung	Dole	Dingboche	…	…
0	1847.1116	-5697.2151	-1090.0370	…	…
1	1847.1116	-5131.2076.	-1090.1052	…	…
2	-1082.1719	-13169.5908	-16482.8053	…	…
3	-2723.9093	-16339.7711	-27038.8177	…	…
…	…	…	…	…	…
…	…	…	…	…	…

Table 45: Output table of the TOTAL SETTLEMENT COSTS AND TOTAL COSTS performance indicators. The cells reports the relevant costs (local currency)

Name	TOTAL SETTLEMENT COSTS						TOTAL COSTS
Time \ Index	Chukung	Dole	Dingboche	…	…	...	...
0	…	…	…	…	…	…	…
1	…	…	…	…	…	…	…
2	…	…	…	…	…	…	…
3	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…

Other outputs

The energy management model also has many other outputs, including the following intermediate variables:

- ✓ AMOUNT OF FIREWOOD EXTRACTED [Kg]: amount of effective firewood extracted in each settlement as regulated by extraction permits considering the Forestry model relevant policy lever
- ✓ AMOUNT OF FIREWOOD [Kg]: amount of firewood that people in each settlement want to extract
- ✓ TOTAL ENERGY DEMAND FOR SPACE HEATING [kWh]: amount of energy demanded for space heating for each building type in each settlement
- ✓ TOTAL ENERGY DEMAND FOR LIGHTING [kWh]: amount of energy demanded for lighting per building type in each settlement
- ✓ OTHER ENERGY DEMANDS [kWh]: amount of energy demanded for other activities considered in the model, including cooking and kitchen utilities, entertainment, water pumping, hot water generation, per building type in each settlement
- ✓ TOTAL ENERGY DEMAND [kWh]: this output represents the total sum of all energy uses according to energy required (value of ENERGY DEMAND) by each settlement
- ✓ CONVENTIONAL AVAILABLE ENERGY [kWh]: is the total energy production from all conventional sources (firewood and fuels, including kerosene, LPG and dung)
- ✓ NON-CONVENTIONAL AVAILABLE ENERGY [kWh]: is the total energy produced by all non-conventional sources (photovoltaic, solar thermal, wind power energy systems)
- ✓ ENERGY PRODUCED BY THE HYDROPOWER PLANT [kWh]: amount of energy produced by each hydropower station
- ✓ HYDROPOWER ENERGY AVAILABLE IN THE SETTLEMENT [kWh]: amount of hydropower energy used in each settlement
- ✓ TOTAL HYDROPOWER ENERGY SUPPLY [kWh]: is the total energy produced (and available) by both already existing and new hydropower stations
- ✓ NON CONNECTED BALANCE [kWh]: energy balance between energy supply and energy demand by utilities that are not connected with electricity
- ✓ CONNECTED BALANCE [kWh]: energy balance between energy supply and energy demand by utilities that are connected with the electricity

For the SNPBZ, these output (intermediate variables), like the performance indicators, can be exported as a table composed of records for each month and columns per each different output as shown below:

Table 46: Output table of the Amount of firewood extracted and Amount of firewood intermediate variables

Name	AMOUNT OF FIREWOOD EXTRACTED					AMOUNT OF FIREWOOD				
Time \ Index	Chukung	Dole	…	…	…	Chukung	Dole	…	…	…
0	…	…	…	…	…	…	…	…	…	…
1	…	…	…	…	…	…	…	…	…	…
2	…	…	…	…	…	…	…	…	…	…
3	…	…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…	…	…

Table 47: Output table of the TOTAL ENERGY DEMAND FOR SPACE HEATING intermediate variable for SNPBZ

Name	TOTAL ENERGY DEMAND FOR SPACE HEATING					
Time \ Index	Chukung	Dole	Dingboche	…	…	...
0	5707.0354	27672.9745	27280.4788	…	…	...
1	5707.0354	26566.0555	27280.4818	…	…	...
2	5095.5673	23245.2986	24132.7688	…	…	...
3	4484.0993	19924.5417	20985.0373	…	…	...
…	…	…	…	…	…	…
…	…	…	…	…	…	…

Table 48: Output table of the TOTAL ENERGY DEMAND FOR LIGHTING intermediate variable for SNPBZ

Name	TOTAL ENERGY DEMAND FOR LIGHTING					
Time \ Index	Chukung	Dole	Dingboche	…	…	...
0	107.7000	871.6500	3215.5956	…	…	...
1	107.7000	871.6500	3215.6609	…	…	...
2	107.7000	871.6500	3216.5087	…	…	...
3	107.7000	871.6500	3217.0956	…	…	...
…	…	…	…	…	…	…
…	…	…	…	…	…	…

Table 49: Output table of the OTHER ENERGY DEMANDS intermediate variable for SNPBZ

Name	OTHER ENERGY DEMANDS					
Time \ Index	Chukung	Dole	Dingboche	…	…	...
0	5707.0354	27672.9745	27280.4788	…	…	...
1	5707.0354	26566.0555	27280.4818	…	…	...
2	5095.5673	23245.2986	24132.7688	…	…	...
3	4484.0993	19924.5417	20985.0373	…	…	..
…	…	…	…	…	…	…
…	…	…	…	…	…	…

Table 50: Output table of the TOTAL ENERGY DEMANDS intermediate variable for SNPBZ

Name	TOTAL ENERGY DEMANDS					
Time \ Index	Chukung	Dole	Dingboche	…	…	...
0	6458.5084	36387.8403	106266.4716	…	…	...
1	6458.5084	35821.8328	106266.5399	…	…	...
2	9387.7919	43860.2160	121659.2399	…	…	...
3	11029.5293	47030.3963	132215.2523	…	…	...
…	…	…	…	…	…	…
…	…	…	…	…	…	…

Table 51: Output table of the CONVENTIONAL AVAILABLE ENERGY and NON-CONVENTIONAL AVAILABLE ENERGY intermediate variables for SNPBZ

Name	CONVENTIONAL AVAILABLE ENERGY					NON-CONVENTIONAL AVAILABLE ENERGY				
Time \ Index	Chukung	Dole	…	…	...	Chukung	Dole	…	…	...
0	...	...	...	...	...	...	...	...	...	...
1	...	...	...	...	...	...	...	...	...	...
2	...	...	...	...	...	...	...	...	...	...
3	...	...	...	...	...	...	...	...	...	...
…	...	...	...	...	...	...	...	...	...	...
…	...	...	...	...	...	...	...	...	...	...

Table 52: Output table of the ENERGY PRODUCED BY THE HYDROPOWER PLANT and TOTAL HYDROPOWER ENERGY SUPPLY intermediate variables for SNPBZ

Name	ENERGY PRODUCED BY THE HYDROPOWER PLANT					TOTAL HYDROPOWER ENERGY SUPPLY
Time \ Index	1	2	…	…	...	
0	...	...	...	...	...	...
1	...	...	...	...	...	...
2	...	...	...	...	...	...
3	...	...	...	...	...	...
…	...	...	...	...	...	...
…	...	...	...	...	...	...

Table 53: Output table of the HYDROPOWER ENERGY AVAILABLE IN THE SETTLEMENT intermediate variable for SNPBZ

Name	HYDROPOWER ENERGY AVAILABLE IN THE SETTLEMENT				
Time \ Index	Chukung	Dole	…	…	...
0	...	...	...	...	...
1	...	...	...	...	...
2	...	...	...	...	...
3	...	...	...	...	...
…	...	...	...	...	...
…	...	...	...	...	...

Table 54: Output table of the CONNECTED BALANCE AND NON CONNECTED BALANCE intermediate variable for SNPBZ

Name	CONNECTED BALANCE				NON-CONNECTED BALANCE			
Time \ Index	Chukung	Dole	…	…	Chukung	Dole	…	…
0	...	...	...	...	...	...	...	...
1	...	...	...	...	...	...	...	...
2	...	...	...	...	...	...	...	...
3	...	...	...	...	...	...	...	...
…	...	...	...	...	...	...	...	...
…	...	...	...	...	...	...	...	...

9.7 Bibliography

AEPC. 1996. *AEPC guidelines for conducting feasibility study of micro-hydropower plants*.

CEE, 1999. *The energy assessment study of Sagarmatha National Park and Chaurikharka VDC (Pharak) area*, WWF Nepal Program, Kathmandu.

DNPWC. 2003. *Sagarmatha National Park and Buffer Zone: Management Plan 2004-2008*. Department of National Parks and Wildlife Conservation (DNPWC), Babar Mahal, Kathmandu.

KBC, 2005. *Energy from the Top of the World*. Khumbu Bijuli Company (KBC), Thame Small Hydropower Plant. The Tenth Anniversary of Establishment, Eds. Baral B. H, Namche Bazaar, Solukhumbu, Nepal.

EDS. 2001. *Micro-hydro electrification survey in Sagarmatha Community Agro Forestry Project Area of WWF Nepal Program*. Preliminary Survey Report (Field Report), Energy Development Services P. Ltd. Kathmandu, Nepal.

HKKH Partnership Project. 2007. *Mission Report* in Sagarmatha National Park Institutional Consolidation for the Coordinated and Integrated Monitoring of Natural Resources towards Sustainable Development and Environmental Conservation in the Hindu Kush-Karakoram-Himalaya Mountain Complex, March 2007.

Protocol Activities (2007-2008) between Kathmandu University (KU) and EV-K2-CN Committee (Ev-K2-CNR) for researches supporting the development of a decision support system in the Hindu Kush-Karakoram-Himalaya Mountain Complex (HKKH Partnership Project), July 2007.

Sherpa. L.N., 2006. *Sagarmatha National Park Management and Tourism Plan 2006-2011*. Department of National Parks and Wildlife Conservation (DNPWC), Sagarmatha National Park, Namche, solukhumbu.

SNP/SCAFP. *Household Survey, 2002*. Sagarmatha National Park and Sagamatha Community Agro-Forestry Project (SNP/SCAFP), Namche, Solukhumbu.

SPCC. 2004. *Annual Progress Report – 2003/2004*. Sagarmatha Pollution Control Committee (SPCC), Namche Bazaar, Solukhumbu.

TRPAP/UNDP. 2006. *Tourism Resources Mapping Profile*, Solukhumbu District, Ministry of Culture and Civil Aviation, UNDP, Nep/99/013.

WWF Nepal Program. 2003. Sagarmatha *Community Agro-Forestry Project: A Retrospectives (1996-2002)*. Kathmandu, Nepal.

Chapter 10

Indoor Air Pollution Model

10.1 Why was this model developed?

In certain circumstances, burning fuelwood in traditional stove could pose a risk to household members. It is known to cause indoor air pollution and considered a threat to the fragile balance of the forest's ecosystem. Therefore, it is important to investigate possible health consequences of air pollution in the household especially by the burning of fuelwood. In fact, exposure to biomass fuels that are used mainly to heat and cook in poorly ventilated homes is one of the greatest risk factors for developing chronic obstructive pulmonary disease (COPD), which is a generally a progressive disease especially when the exposure to pollutants is not interrupted or absolutely reduced.

Combustion of biomass fuels may cause high concentrations of carbon monoxide (CO) in indoor air. The effects of CO exposure in the long run can vary greatly from person to person depending on age, overall health and especially on the concentration and length of exposure. An indicator of indoor air pollution is represented by the CO density in each house, which negatively influences of the health of its inhabitants. Kitchen appliances such as wood stoves and fireplaces, leaking chimneys and furnaces, gas stoves, gas water heaters, back-drafting from furnaces, unvented kerosene and gas space heaters, generators and other gasoline powered equipment can be the significant sources of indoor air pollution.

Due to the fact that indoor pollution induced by biomass smokes in the homes is rampant in the hills of Nepal, this model was developed under the HKKH Partnership Project with the aim to assess the state of respiratory health of people living in the villages of the Sagarmatha National Park and its Buffer Zone (SNPBZ) and also propose solutions to improve their health. The studied villages are only attainable afoot and therefore not affected by traffic pollution or atmospheric pollution from industrial installations.

In detail the model is conceived to:

- identify indoor air pollution conditions in relationship with energy sources (fuel and fuelwood) and possible devices to increase the quality of the indoor air
- identify people's respiratory health conditions.

10.2 What is the context in which the model was developed?

Introduction

Pandey and Basnet (1987) have found a strong correlation between the prevalence of chronic bronchitis and indoor smoke pollution in Nepal. It was reported that 31% of the bronchitis cases were due to indoor smoke pollution in Jumla district in Far West Nepal, 17% in Sundarijal and Bhadrabas in Kathmandu district, 13% in Parasauni in Bara district (Central Terai), and 11% in urban Kathmandu. They indicated that twice as many traditional cooking stove owners complained of eye irritation and coughing than owners who used the improved cooking stove.

Fuelwood and other biomass (including animal waste, vegetable waste, Kerosene, LPG, coal) are major sources of indoor air pollution in domestic and commercial areas of Nepal (MOPE, 2001). Fuelwood is still the most common source of fuel in both sectors, but wood and dung are mostly used in domestic context, while the use of kerosene and coal is used mostly by the commercial sector.

The indoor air in most rural areas is polluted because of combustion of biomass in poorly ventilated rooms. Indoor air pollution induced by biomass fuels used in the homes for heating spaces and cooking is increasing in the villages of the SNPBZ and is one of the major causes of COPD in the local population.

Qualitative analysis of the Indoor Air Pollution Model

The first step in the overall modeling process adopted under the HKKH Partnership Project has been the qualitative analysis of the socio-ecological system of SNPBZ on the basis of existing studies, expert knowledge and stakeholders (Salerno *et al.*, 2009). In this context, a qualitative model on the issue of indoor air pollution in the SNPBZ has been developed mainly to analyse and assess the health status of local population.

The conceptual diagram is shown in Figure 11.

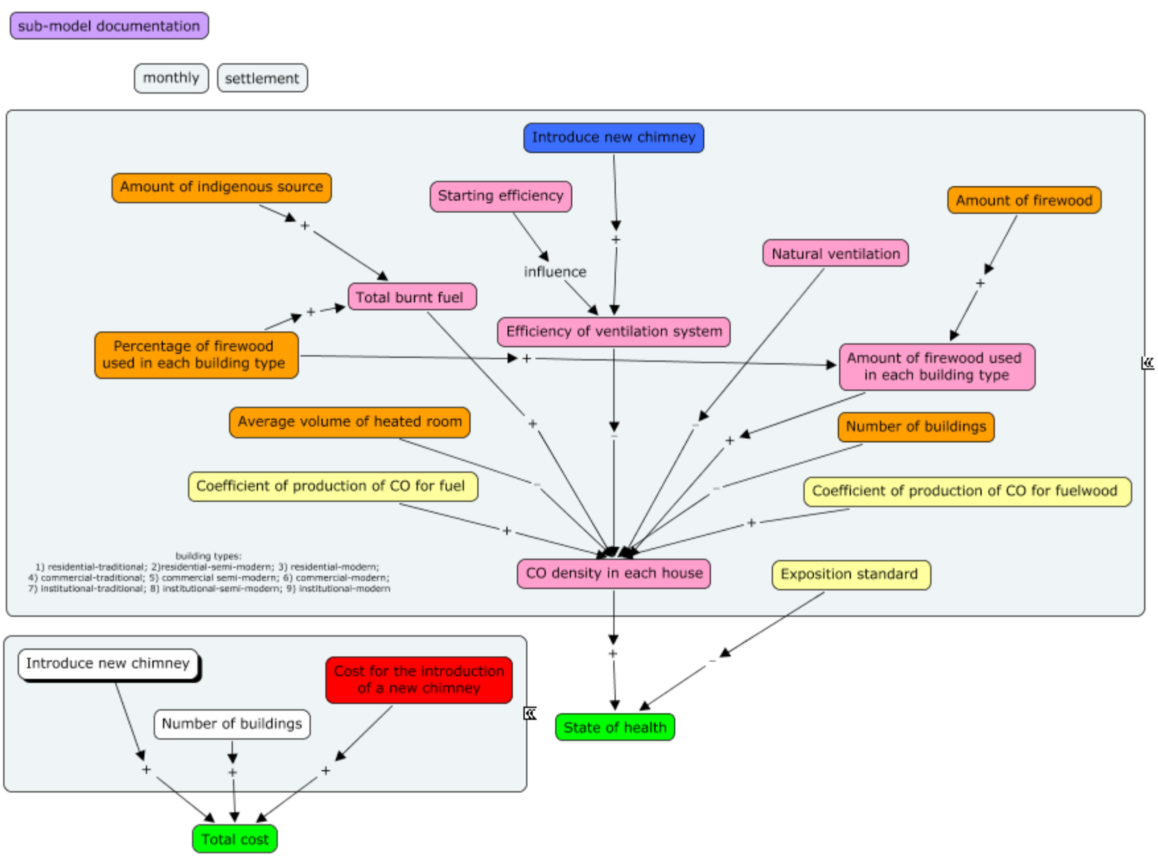


Figure 11: Qualitative diagram of the indoor air pollution model

The conceptual diagram for the Indoor air pollution model is divided into two main concepts: bigger concept and smaller concept. The bigger concept (the illustration at the top in Figure 11) is concerned with indoor air conditions due to CO pollution by building type in each settlement. The nine different types of building are: residential-traditional, residential-semi-modern, residential-modern, commercial-traditional, commercial-semi-modern, commercial-modern, institutional-traditional, institutional-semi-modern, institutional-modern. The smaller concept (illustration in red) describes the relevant costs tied to the construction of new chimneys, aimed at improving the ventilation system efficiency in the houses as enforced by the management policy.

As shown in Figure 11, a positive relationship of the amount of indigenous source and the percentage of firewood used in each building type exists with the *total burned fuel* and also positively correlated with *amount of firewood*, which is a link to the energy sub-model. The total burned fuel is then positively correlated with the *CO density in each house*, which also depends positively on the *coefficient of production of CO for firewood* (illustrated in yellow) as well as on the *amount of firewood*, while it is in inverse relation to the *average volume of heated rooms, number of buildings, efficiency of ventilation system* and *natural ventilation.* The introduction of a new chimney in the house may increase the *efficiency of ventilation system*, which is also influenced by the *starting efficiency,* and represents the main management policy to reduce the amount of CO density in the house. As shown in Figure 11, the CO density in each house negatively influences the *state of health* of each person, which gets worse if the CO density in the house increases.

The smaller concept at the bottom of the diagram illustrates the economical aspects of introducing a new chimney in each household, including costs incurred considering the total number of buildings in the villages in SNPBZ.

10.3 How does this model work?

The Indoor air pollution model estimates the state of health of the people in SNPBZ who lives in houses with a high level of CO density. The model considers and runs in the settlement level with monthly time step.

Particularly, the user can use the model in a simple way to assess the combustion process of firewood and other fuels (e.g., animal wastes or kerosene or LPG) to calculate the CO density in each house per building type and the state of respiratory health of inhabitants in each selected settlement.

At the same time, the model allows the user to evaluate the possibility of improving the indoor air quality by introducing a new chimney in the house, taking into consideration the costs incurred to do so.

The model first calculates the total monthly amount of fuel and firewood burnt by each selected settlement within the studied area. Users can run the model for a maximum of 25 settlements as a generic model with nine building types: residential-traditional, residential-semi-modern, residential-modern, commercial-traditional, commercial-semi-modern, commercial-modern, institutional-traditional, institutional-semi-modern, institutional-modern. Both the number of settlements (25) and type of buildings (9) to be considered are settled by default in the model, but if users want to consider less settlements/type of buildings, they can simply to put the value 0 for the concerned missing data. In this model also for the case study of SNPBZ, same 18 settlements as presented in tourism flow model are considered.

The amount of burned firewood and fuel depend on the number of the local population and the number of tourists entering the park, including visitors, porters and guides (calculated through the Tourism flow model). Beginning with the drivers of the system like tourists and inhabitants as well as the amount of both fuel and firewood used for cooking and space heating, which are influenced by the management lever implemented in the Energy management model, the total amount of burnt fuel can be calculated through the model.

Considering, on the one hand, the coefficient of production of CO for both fuel and firewood and, on the other hand, the average volume of heated rooms, number of buildings in each settlements (the latter two provided by the Energy model) and efficiency of the ventilation system, it is possible to calculate the average CO density in each house per building type.

The average state of the people's health for each type of building in the selected settlement can be assessed by considering the ratio between CO density in the house and relevant average tolerance of each person (expressed by a concentration of tolerance).

The only management policy applied to this model concerns the reduction of the CO density in the houses by introducing a new chimney in order to improve the efficiency ventilation system. The costs incurred are also analysed in the model.

10.4 The model inputs

The Indoor air pollution model includes two kinds of input data or input variables:

- INDOOR AIR POLLUTION PARAMETERS
- INDOOR AIR POLLUTION DATA

These input variables are either fixed parameters or variable parameters: For instance,

Fixed parameters:

- *Natural ventilation*: natural ventilation in the buildings
- *Starting efficiency*: efficiency of ventilation systems
- *Percentage of firewood used in each building type*: percentage of firewood used in each building type calculated considering the number of bed and the number of buildings in each settlement and for each building type

Variable parameters:

- Cost for the introduction of a chimney
- Coefficient of production of CO from fuel
- Coefficient of production of CO from fuelwood
- Exposition standard

These input variables are connected with an input table in *.csv file format as indicated in Table 55.

Table 55: *Input variables and correlated input table .csv files of the indoor air pollution model*

Input variable/s	Input table (*.csv format)
INDOOR AIR POLLUTION PARAMETERS	Indoor parameters.csv
INDOOR AIR POLLUTION DATA	data_indoor.csv

A brief description of each input table is provided below. An example of each table is also furnished with input data specifics for the SNPBZ case study. However, users can provide their own input files for the area of study simply by editing (or replacing) the current files.

Indoor parameters.csv

The *Indoor parameters.csv* is composed of three columns indicating the following parameters:

- *exposition standards* [g/m3]: average indoor air concentration of CO tolerable by one person
- *coefficient of production of CO for fuel* [g/Kg]: amount of CO produced by the combustion of a kilogram of generic fuel (dung for SNPBZ)
- *coefficient of production of CO for fuelwood* [g/Kg]: amount of CO produced by the combustion of a kilogram of fuelwood

Table 56: Example of indoor_parameters.csv input table for SNPBZ

exposition standards	coefficient of production of CO for fuel	coefficient of production of CO for fuelwood
0.01	4.967	3.48

Data_indoor.csv-

The *data_indoor.csv* input table is composed of six columns and reports particularly on the following data:

- *Efficiency of ventilation system/Starting efficiency* [%]: initial efficiency of ventilation systems in each settlement and in each building type currently available
- *Natural ventilation* [No.]: Reduction coefficient due to the natural ventilation of each house
- *Percentage of firewood used in each building type* [%]: percentage of firewood used in each building type and in each settlement

An example of input table structure is provided here below for the case study of SNPBZ. Users can provide their own input files for the area of study simply by editing (or replacing) the current files.

Table 57: Example of data_indoor.csv input table for SNPBZ

Settlement	Settlement index	Building type	Efficiency of ventilation system [%]	Natural ventilation	Percentage of firewood used in each building type
Chukung	1	residential_traditional	20	0.211	4
Chukung	1	residential_semimodern	0	0	0
Chukung	1	residential_modern	65	0	0
Chukung	1	commercial_traditional	35	0	0
Chukung	1	commercial_semimodern	0	0	96
Chukung	1	commercial_modern	65	1.06	0
Chukung	1	institutional_traditional	65	0	0
Chukung	1	institutional_semimodern	0	0	0
Chukung	1	institutional_modern	0	0	0
Dole	2	residential_traditional	20	0.211	5
Dole	2	residential_semimodern	0	0	5
Dole	2	residential_modern	65	0	0
Dole	2	commercial_traditional	35	0	0
Dole	2	commercial_semimodern	0	0	89
Dole	2	commercial_modern	65	1.06	0
Dole	2	institutional_traditional	65	0	0
Dole	2	institutional_semimodern	0	0	0
Dole	2	institutional_modern	0	0	0
Dingboche	3	residential_traditional	20	0.211	5
Dingboche	3	residential_semimodern	0	0	3
Dingboche	3	residential_modern	65	0	0

Dingboche	3	commercial_traditional	35	0	36
Dingboche	3	commercial_semimodern	0	0	56
Dingboche	3	commercial_modern	65	1.06	0
Dingboche	3	institutional_traditional	65	0	0
Dingboche	3	institutional_semimodern	0	0	0
Dingboche	3	institutional_modern	0	0	0
...		...	...	...	...

10.5 Management levers

The management lever was identified and evaluated in collaboration with local and national stakeholders and experts to ensure that it reflects viable option for improving the management of SNPBZ by means of simulating hypothetical scenarios, which is worth exploring.

The user can operate on the model inputs to simulate different scenarios by changing the management lever.

The effect of user-defined management lever settings on the system can be assessed by looking at the changes in the system's "performance indicator" over time. The performance indicator is explained in detail in the next section.

Management lever "Introduce new chimney"

Usually the most effective way to improve indoor air quality is to eliminate individual sources of pollution or to reduce their emissions. In many cases (e.g., gas stoves) controlling the source is also a more cost-efficient approach to protecting indoor air quality than increasing ventilation because increasing ventilation can increase energy costs (US-EPA). However, this may not be true when the source of indoor air pollution is represented by fireplaces or wood stoves as in the majority of houses in the SNPBZ.

This model entails only one management lever that is designed to improve ventilation system efficiency in the house in order to reduce the CO density that is responsible for domestic air pollution. Particularly when operating on this management lever, the user will directly act by changing the efficiency of the ventilation system when an introduction of a new chimney in the house is assumed. The variable INTRODUCE NEW CHIMNEY will assume value 0 or 1. If the value is 0, the efficiency of the ventilation system will be the initial one. If it is 1, the efficiency of the ventilation system will be a value between 0 and 1, for example 0.8, indicating a high efficiency.

The following table lists this management lever schematically and provides information on the way the value for the management lever can be set. It shows minimum and maximum value of management lever and its types: whether it requires an integer (int) or real value (real) to be defined and the unit of the lever.

Table 58: Policy lever for the indoor air pollution model, including specification and connected variable

Policy Lever	Specification	Variable/s name	Unit and Description
Policy lever_ Introduce new chimney	It represents the possibility or not to introduce a new chimney. The value is 1 when it is envisaged the construction of a new chimney, otherwise it remains 0.	Introduce new chimney	[0,1], int

10.6 The model outputs

The model provides three different outputs that include two model performance indicators and an intermediate variable that are described hereafter. By operating on the management levers of the model, the user can evaluate their effects on those outputs and obtain possible scenarios on the solid waste condition in the studied area.

Indicators of performance

This model output will tell the user the “performance of the system” based on the management lever-values selected before and after running the model. By means of interpreting the values of the performance indicators through simulation, the user will obtain information about the potential positive and negative effects of the chosen management option (management lever settings). Again, the performance indicators have been developed in collaboration with local and national stakeholders and experts and reflect key system dynamics of high relevance for managers.

These indicators of performance provided by this model are:

- ✓ STATE OF HEALTH: represents an index which shows the gravity of the disease in the settlement. It will assume an integer value comprised from 1 to 5 according to the gravity of the disease (COPD).
- ✓ TOTAL COST: the implementation of the management lever is associated with financial costs, particularly the costs incurred by the construction of a new chimney in household. The model simulates reality; for instance, the extent to which management options are put into practice has an effect on the overall budget required. In our model, this means that the cost incurred in implementing a management option is dependent on the value chosen for a management lever. This indicator simply will be 0 if the policy will not be implemented. It will assume the cost of the chimneys depending on whether the user will choose to introduce a new chimney or not.

For the SNPBZ, all these outputs can be exported as a table composed of records for each month and which includes columns as reported by each different output. An example of an output table for each of the model performance indicators is provided below.

Table 59: Output table of the STATE OF HEALTH performance indicator

Output variable	Index 1 (settlement)	Index 2 (building type)	Description
MONTH			Simulation month
STATE OF HEALTH	Chukung	residential_traditional	Average State of health of residential traditional house of the Chukung
	residential_semimodern		Average State of health of residential semimodern house of the Chukung
	...		...
	...		...
	institutional_modern		Average State of health of institutional modern building of the Chukung
	Dole	residential_traditional	Average State of health of residential traditional house of the Dole
	...		...
	institutional_modern		Average State of health of institutional modern building of the Dole
	...	...	...
	...		...
	...		...

Table 60: Output table of the TOTAL COST performance indicator

Output variable	Index 1 (settlement)	Index 2 (building type)	Description
MONTH			Simulation month
Total cost [NRs for SNPBZ]	Chukung	residential_traditional	Total cost related to the introduction of new chimney for residential traditional house of the Chukung
	residential_semimodern		Total cost related to the introduction of new chimney for residential semimodernl house of the Chukung
	...		...
	...		...
	institutional_modern		Total cost related to the introduction of new chimney for institutional modern house of the Chukung
	Dole	residential_traditional	Total cost related to the introduction of new chimney for residential traditional house of the Dole
	...		...
	institutional_modern		Total cost related to the introduction of new chimney for institutional modern house of the Dole
	...	...	...
	...		...
	...		...

Other outputs

The following intermediate variable represents other output of this model:

- ✓ CO DENSITY IN EACH HOUSE: this variable represents the daily average density of CO in each house per building type in each selected settlement.

This output also can be exported as a table composed of records for each month and which includes columns as reported in Table 60.

Table 61: Output table of the CO DENSITY IN EACH HOUSE intermediate variable

<table>
<tr><th>Output variable</th><th>Index 1
(settlement)</th><th>Index 2
(building type)</th><th>Description</th></tr>
<tr><td>MONTH</td><td></td><td></td><td>Simulation month</td></tr>
<tr><td rowspan="11">CO density in each house [g/m^3]</td><td>Chukung</td><td>residential_traditional</td><td>Average CO density in each residential traditional house of the Chukung</td></tr>
<tr><td colspan="2">residential_semimodern</td><td>Average CO density in each residential semimodern house of the Chukung</td></tr>
<tr><td colspan="2">...</td><td>...</td></tr>
<tr><td colspan="2">...</td><td>...</td></tr>
<tr><td colspan="2">institutional_modern</td><td>Average CO density in each institutional modern building of the Chukung</td></tr>
<tr><td>Dole</td><td>residential_traditional</td><td>Average CO density in each residential traditional house of the Dole</td></tr>
<tr><td colspan="2">...</td><td>...</td></tr>
<tr><td colspan="2">institutional_modern</td><td>Average CO density in each institutional modern building of the Dole</td></tr>
<tr><td>...</td><td>...</td><td>...</td></tr>
<tr><td colspan="2">...</td><td>...</td></tr>
</table>

10.7 Bibliography

Fasano, V., B. Basnyat, D. Legnani, M.Farinatti and A.L. Cogo. _______. *Early airway obstruction in young non smoker residents in mountain villages in Nepal*.

For toxicity of CO: http://en.wikipedia.org/wiki/Carbon_monoxide_poisoning#_note-8

For FEF_{25-75}: http://www.medal.org/visitor/www%5CActive%5Cch8%5Cch8.01%5Cch8.01.03.aspx

For FEV1/FVC and FEV1: http://www.my-personaltrainer.it/spirometria.html (Italian)

Cogo, A., D. Legnani, L. Mestri, B. Basnyat. ______. *Respiratory health and indoor pollution in residents at high altitude in Nepal in Health and Height*. Proceedings V World Congress on Mountain Medicine and High Altitude Physiology.

Pandey, M.R. 1984. *Domestic smoke pollution and chronic bronchitis in a rural community of the hill region of Nepal*. Thorax, 39: 337-339.

Pandey, M. and B. Basnet. 1987. *Chronic bronchitis and cor pulmonale in Nepal, A scientific epidemiological study monograph*. Kathmandu: Mrigendra Medical Trust, Kathmandu.

MOPE, 2002. *State of the Environment 2001*, Ministry of Population and Environment (MOPE). Kathmandu, Nepal.

Forestry Model

11.1 Why was this model developed?

The forestry model was developed to address the problem of forest degradation in protected areas, which is a key management concern as the rising population and increasing tourism activities in these areas lead to a high demand of fuelwood as main source of energy. The potential demand by local people and tourists may exceed productive capacity if it is not compensated by the development of alternative energy sources and adequate management plans to regulate fuelwood collection and promote a rational use of forest products.

Therefore, the overall aim of this model is to support the users (including local stakeholders and decision makers) in assessing the total biomass of forests in selected protected areas by mainly analysing the effect of fuelwood extraction on forest condition. The key variables influencing forest condition in the selected protected areas have been defined as “management levers” of the model, which can be changed by the user to simulate different scenarios.

In particular, the model was developed under the HKKH Partnership Project as a case study of the Sagarmatha National Park and Buffer Zone (SNPBZ). Through discussions held with local and national protected area managers, experts and during relevant research activities carried out in the framework of the Project itself, forest degradation and loss of forest biomass have been identified as key management problems with regard to rising energy demand and increasing extraction of fuelwood driven mainly by the rise in tourism. The forest resources and its biomass are linked with various economic and ecological factors including tourism development. Because of the rise in tourism, effective conservation of forests and alpine areas in the park region is likely to continue to be a major challenge.

11.2 What is the context in which the model was developed?

Introduction

Despite more than a quarter century of local, national, and international conservation efforts, forest degradation and loss of alpine shrub juniper continue to be significant environmental issues in several parts of the SNPBZ. Fuelwood constitutes the major source of energy for the majority of people in the park and despite the increasing trend in the demand of alternative energy, which is still minimally developed, the pressure on accessible forests for meeting household energy demands may continue in the park. Similarly, impact of rising population and tourism activities in the area has increased the demand of fuelwood, particularly for heating and cooking. Tourism has brought prosperity to many local people in the area, but has also contributed to the thinning of forests as tourism is associated with lodge construction, heating the inns and increase in the numbers of porters. The forest resources also support the livelihood of the local population in the form of a variety of products that are extracted from forests: fuelwood, food, timber, fodder, grazing and medicinal resources.

Fuelwood consumption varies depending on the season, wealth and forest accessibility. The total annual wood production from the forests of SNPBZ is estimated at 15,000 metric tones. The potential demand by local people and tourists may exceed beyond its productive capacity if not compensated by other substitutes. Its continued use by lodges and expeditions puts pressure mainly on forests with the highest altitudes and shrubland (juniperus, birch and rhododendrons). As per Himali National Park Regulation 2036, the Sagarmatha National Park (SNP) permits local residents to collect firewood for two months in a year. Oak, rhododendron and birch are the most commonly used species for fuelwood.

Although various energy alternatives to fuelwood such as electricity, solar energy, kerosene and LPG have been introduced in SNPBZ, fuelwood is still a major source of energy, particularly for cooking and space heating purposes. However, there is inadequacy of fuelwood (deadwood) to fulfill the increasing demand. Therefore, on one hand, the protection of SNPBZ forests, ensuring that human uses are in balance with the natural recovery capacity, for instance, by promoting alternative energy sources is necessary. On the other hand, it seems that it is also necessary to make forest use regulatory system more systematic and site specific, and promote a responsible use of forest products to guarantee the conservation of the whole SNPBZ natural resources.

The SNPBZ Management Plan 2004 – 2008 provides a simple description of the current management system of the forest in SNPBZ and documents the strategies to reduce fuelwood consumption, giving priority to renewable and environmentally sound options such as hydropower, solar, thermal and wind energies.

Singhi Nawa is an indigenous natural resources management practice in the Khumbu region. Before establishment of SNP, local Sherpas used to manage their forest resources by formulating local rules and regulations known as *Singhi Nawa* practice. The *Nawa* system was responsible for enforcing rules and regulations to maintain forest product harvest calendar, regulate harvest and penalise offenders and maintain transhumance and grazing. Currently, the *Nawa* system is not in practice in the majority of Sherpa villages in Khumbu. After the establishment of SNP, all forest areas were managed under the protected area management system. All the forest that falls inside the park boundary is managed by the Park. The fuelwood and timber extraction from this forest is based on the specific forest extraction rule and regulation set up by the Park. Less than 5% of the park area is forested and 15% of the forest area exists in the buffer zone. Forests in the buffer zone are being managed by local people as community forests. Currently, five Buffer Zone Community Forest User Groups are running the management of community forests in the buffer zone (Pharak). They regulate the harvest of forest products by formulating rules and regulations, taking action against illegal logging and timber smuggling, managing forest nurseries, undertaking plantation programs and mobilising users for private plantation. The regulation currently in place allows maximum of two people per household in the SNPBZ to collect fuelwood twice a year for a period of 15 days. This way a maximum amount of 60 loads, commonly known as “Bharis” in Nepali (summing up to 1,200 kg at 50 kg per Bhari), can be collected per household in the overall 30-day-long collection period per year. The amount corresponds to a daily collection amount per household of 100 kg (50 kg per person) during the collection period or a daily average of 3.3 kg per day per household. The collection regulation can change slightly from one buffer zone community forest to another. Moreover, monasteries also manage some of the forest portion in the SNPBZ as ‘religious forest.’ The large area of the forest in the buffer zone has been registered as private forests, which are controlled by individuals. The model in the case study of SNPBZ considers forest inside the park and mainly two community forests Phakding and Lukla in the buffer zone.

Research activities were conducted under the HKKH Partnership Project in order to investigate the current state and structure of the forest, and on the consequent fuelwood consumption in the park area. Information acquired and data collected have been crucial in developing this model.

Qualitative analysis of the Forestry Model

The first step in the overall modeling process adopted under the HKKH Partnership Project has been the qualitative analysis of the socio-ecological system of SNPBZ on the basis of existing studies, expert knowledge and stakeholders (Salerno *et al.*, 2009). In this context, a qualitative model (Figure 12) on forestry in the SNPBZ has been developed to analyse the pressure on forest condition stemming from fuelwood collection by assessing the *total biomass* of the park.

As shown on the conceptual diagram (i.e., the qualitative model) in Figure 12, the total forest biomass per each forest area can be determined by considering the actual forest biomass (*initial biomass value*) and the maximum biomass accessible by the forest itself as well the forest growth rate. Moreover, the total forest biomass is negatively correlated with the *amount of firewood extracted from the forest area* itself and decreases with the increasing extraction of firewood. As the concept map illustrates, establishing permits and regulations as envisaged by the relevant management lever of the model may influence the amount of firewood extracted in each forest area. The model is linked with the Energy model, which provides the amount of firewood that is extracted by inhabitants of each settlement (*amount of firewood extracted per settlement*). This data is then combined (aggregated) in the model with an input variable (namely *partitioning*) indicating the percentage of wood that is extracted at each settlement in the selected forest areas.

Possible costs (illustrated in red) concerning the management policy implemented in the model are also considered as well.

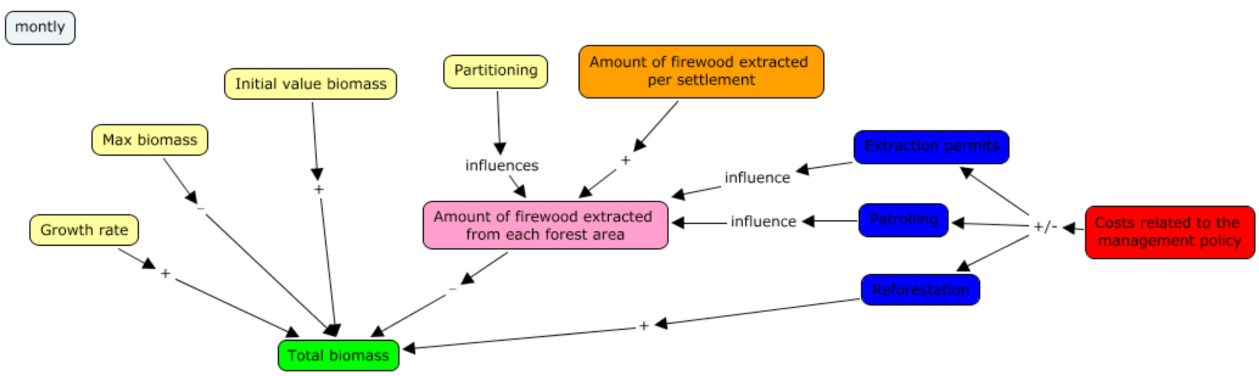


Figure 12: Qualitative diagram of the forestry model

11.3 How does this model work?

This model allows the user to make an assessment of the total forest biomass of 13 selected forest areas based on the amount of firewood extracted by local population of 18 settlements. Both the number of forest areas and settlements to be considered is settled by default in the model. However, if users want to consider less sites, they simply to put the value 0 for the concerning missing data. For the case study of SNPBZ, 18 settlements are considered, which are listed in the Tourism flow user manual, while the 13 forests considered in the model are indicated hereafter in the next section. The model runs at monthly time basis. The data received from the in-depth field research and literature review by researchers under the research framework of the project are inputted into the model.

11.4 The model inputs

Four different types of input data per forest area are considered in the Forestry model. Particularly they are:

- ✓ GROWTH RATE [No./year]: average growth rate of each forest area;
- ✓ BIO_MAX [Kg]: maximum threshold of forest biomass accessible by the forest area according to the species present in that area;
- ✓ BIO_0 [Kg]: initial forest biomass value (represents the starting point of the simulation process);
- ✓ PARTITIONING [%]: percentage of wood extracted by each settlement (by people of the settlement) in each forest area;
- ✓ EXTRACTION LIMIT [Kg/month]: extraction limit per month for each of the settlements.

The four input variables described above are connected with an input table in *.csv file format, as indicated in the following table:

Table 62: Input variable and connected input table.csv files

Input variable	Input table (*.csv format)
GROWTH RATE BIO_MAX BIO_0	data_forest.csv
PARTITIONING	partitioning.csv
EXTRACTION LIMIT	data_forest_settlement.csv

A brief description of each input table is provided below. Users can provide their own input data files to implement the model simply by editing (or replacing) the current files.

Data_forest.csv

The *data_forest.csv* input table contains data regarding the initial value of the forest biomass, the maximum threshold of forest biomass accessible by the forest as well as the average growth rate of the forest per each selected forest area (total of 13 forests).

The input table is composed of four columns concerning:

- *Forest index* [No.]
  An index (i.e., a whole number from 1 to 13) identifies each forest area considered. Particularly, for the case study of SNPBZ the indexes are assigned to the selected forests as follows:

  1 → Lukla
  2 → Phakding
  3 → Namche
  4 → Below Kongde-Sotarmo
  5 → Dole
  6 → Phortse
  7 → Tengboche north
  8 → Opposite Tengboche
  9 → Kele
  10 → Omaka
  11 → Pare
  12 → Debuche
  13 → Tengboche

- *Bio_0* [Kg]
- *Bio_max* [Kg]
- Grow_rate [No.]

Table 63: Example of data_forest.csv input table for SNPBZ

Forest index	Forest name	BIO_0 [Kg]	BIO_MAX [Kg]	growth_rate [monthly]	Biomass reforestation [Kg]
1	Lukla	35033805	1.05E+08	0.000212	0
2	Phakding	5077927	15233782	0.00871	0
3	Namche	1815234	5445703	0.002237	0
4	Below Kongde-Sotarmo	7117103	21351308	0.001063	0
5	Dole	224032.5	672097.4	0.000886	0
6	Phortse	2937236	8811709	0.000448	0
7	Tengboche North	325545	3255450	0.005709	0
8	Opposite Tengboche	12629993	37889980	0.000117	0
9	Kele	164795.6	494386.7	0.000886	0
10	Omaka	6351930	19055789	0.000448	0
11	Pare	589984.2	1769953	0.000886	0
12	Debuche	626516	1879548	0.001677	0
13	Tengboche	471542	1414626	0.000886	0

Partitioning.csv

The *partioning.csv* input table contains the percentage of wood extracted by each settlement in each forest. Since the fuelwood in the SNPBZ is not imported from outside, the total percentage is set to 100. This table and the relevant variables aggregate the amount of wood extracted by people living in each settlement into a different number of forests.

The input table is composed of three columns:

- *Forest_Settlement_Index [No.]:* this column reports the indexes that identify each forest area that was considered. For the SNPBZ, a specification of the correspondence between indexes and forests name is provided above in the data_forest.csv file description.
- *Settlement* [name]
- Partitioning [%]

Table 64: Example of partioning.csv input table for SNPBZ

Forest_Settlement_Index	*Settlement*	*Partitioning*
1	Chukung	0
1	Dole	0
1	Dingboche	0
...	...	...
1	Lukla	100
...	...	...
2	Chukung	0
2	Dole	0
2	Dingboche	0
...	...	...
...	...	...
2	settlement_y	0
3	Chukung	0
3	Dole	0
...	...	...
4	Namche	83
...	...	...

Data_forest_settlement.csv

The *data_forest_settlement.csv* input table is composed of three columns:

- *Settlement* [Name]
- *Extraction Limit [Kg/month]:* this column refers to wood extraction limit for each of the settlements per month.
- Patrolling[No.]: this column reports whether there is patrolling by forest guards or local authorities (0: no patrolling, 1: patrolling).

Table 65: Example of data_forest_settlement.csv input table for SNPBZ

Settlement	extraction limit [Kg/month]	patrolling
Chukung	1500	0
Dole	2500	0
Dingboche	13000	0
Dzonglha	500	0
Gokyo	2250	0
Gorakshep	1500	0
Khumjung	40750	0
Lobuche	1750	0
Lukla	38250	0
Machherma	3000	0
Marlung	2750	0
Namche	35250	0
…	…	…

10.5 Management levers

The Forestry model was developed with the intention of exploring different solutions to mitigate the problem of forest degradation in SNPBZ mainly caused by the continued extraction of fuelwood due to growing energy demands driven by a rise in tourism in the area. In order to identify the proper management levers to adopt as well as the performance indicator/s, several workshops with managers were held during the qualitative analysis step within the modelling process. Consequently, three management levers were identified for SNPBZ.

- Extraction permit
- Biomass reforestation
- Patrolling

The management lever *Extraction permit* proposes the establishment of policies to regulate fuelwood extraction that can be enforced also by patrolling. It is represented by a variable, namely, *Extraction permit*, indicating the amount in Kilograms of fuelwood that local population of each settlement is allowed to extract. The user may change the amount of fuelwood that people are allowed to collect from each forest and assess how this may affect the total available forest biomass.

The management lever, *biomass reforestation* is concerned with the introduction of additional forest biomass in the selected forest, which is also expressed in Kilogram unit. The third management lever included in the model is *patrolling* that regulates extraction of forest biomass through its presence or absence in the model.

Table 66: Policy levers of the forestry model

Policy Lever name	Specification	Variable name	Unit and Description
Policy lever_ extraction permit	This value denotes the amount of fuelwood that inhabitants of each settlements are allowed to extract from the selected forest	Extraction permit	[Kg], int
Policy lever_ reforestation	This value denotes the amount of biomass introduced by inhabitants of each settlements to the selected forest	Biomass reforestation	[Kg], int
Policy lever_patrolling	This is a management lever regulating the extraction of forest biomass from the forest	Patrolling	[0,1], bol, [No.] Value is 0 if the policy is not applied, but 1 if patrolling is present

Legal and illegal fuelwood extraction can be assumed to be primarily influenced by the gap between demand and supply (the current state of the model does not model the two separately, however). However, data on demand is available (for example, from the Energy model); policy-levers concerning fuelwood dynamics in the forestry model could be conceptualised as levers that “mediate” the relation between demand and supply.

The “fuelwood extraction policies” and “patrolling” can be very closely connected, in that “patrolling” is the necessary implementation component of extraction policy that ultimately enforces compliance with the policy, so the two should not be conceived as independent levers. In addition, these levers are also dependent on the level of congruence/discrepancy between fuelwood demand and supply.

11.6 The model outputs

Indicator of performance

The output of the Forestry model is the performance indicator "BIOMASS", which is the dynamic element of this model and represents the amount in Kilograms of forest biomass in each forest area per each time step. This value depends on the growth and extraction "flows" in each time step. This output can be exported as a table that is described in the next section.

Other output

The Forestry model provides also the following intermediate variable as output:

- ✓ AMOUNT_OF_FUELWOOD_EXTRACTED_PER_FOREST: amount in Kilograms of fuelwood extracted in each forest area. This variable also represents the aggregation by forest area of the variable *Amount of firewood* from the Energy model and disaggregated for settlement.

For the SNPBZ, both of these outputs can be exported as a table composed by records for each month, as shown in Table 67:

Table 67: Output variables of the forestry model

Column	Output variable	Index 1 (forest area)	Description
1	MONTH		Simulation month
2	BIOMASS [Kg]	1	Total amount of biomass each month in the first forest area
3		2	Total amount of biomass each month in the second forest area
4		3	Total amount of biomass each month in the third forest area
...		...	...
15	AMOUNT_OF_FUELWOOD_EXTRACTED_PER_FOREST [Kg]	1	Amount of fuelwood extracted each month in the first forest area
16		2	Amount of fuelwood extracted each month in the second forest area
17		3	Amount of fuelwood extracted each month in the third forest area
...		...	...
...		...	...

11.7 Bibliography

DNPWC, 2003. *Sagarmatha National Park Buffer Zone: Management Plan 2004 – 2008*. Department of National Parks and Wildlife Conservation (DNPWC) Babar Mahal, Kathmandu.

Sherpa. L.N., 2006. *Sagarmatha National Park Management and Tourism Plan 2006-2011*. Department of National Parks and Wildlife Conservation (DNPWC), Sagarmatha National Park, Namche, solukhumbu.

Stevens, F.S. 1996. *Claiming the high ground: Sherpas, subsistence and environmental change in the highest Himalayas*. Motilal Banarsidass Publishers, Delhi.

Water Pollution Model

12.1 Why was this model developed?

Managing water resources is an integral part of maintaining essential life support systems and the well-being of the local population, Tourism, in particular, plays a significant role in impacting water quality conditions in protected areas, and, therefore, this issue needs to be addressed when developing environmentally sound management plans.

In order to measure the quality of local water supply and human impact on the biophysical environment, relationship between specific water quality parameters and anthropic conditions need to be examined. Water quality information may be used to determine the consequences of human defecation and/or eutrophication of surface and groundwater on four main potential uses of water including human/domestic use, recreation, irrigation and aquatic life maintenance.

In order support decision makers in developing appropriate and environmentally-sustainable management plans addressing the issue of water pollution in protected areas mainly due to civil waste and agricultural pollutants, a model on water pollution has been developed. In particular, the model has been implemented for the case study of the Sagarmatha National Park and Buffer Zone (SNPBZ) where the increasing number of tourists is diminishing the quality of water. The SNPBZ is facing massive anthropogenic disturbances that can cause serious environmental consequences to the unique ecosystem. According to the local residents and visitors to SNPBZ, disposal of human excretion is one of the most serious issues facing the park. Many foreign expedition teams are reported to have left a great deal of garbage in different Himalayan peaks, polluting the environment. Source of pollution is no longer confined to solid waste; water sources along the major trails are being contaminated from improper effluent discharge, human excretion and garbage dumping. Sewerage and toilet waste can be found piped into nearby streams and rivers. Lack of public toilets along the trails has forced travellers to often use trailside bushes. On the other hand, in some places, private toilets are built too close to rivers and streams. Furthermore, most private and public toilets do not have septic tanks and therefore, human excretions are not properly disposed. The temporary pit toilets used by trekking groups are becoming a health hazard too. All this leads to land and water pollution. Also, because of the lack of proper drainage system in the settlements, waste is flowing into streets and nearby streams, indicating an urgent need for proper sanitation regulations in the villages.

The overall aim of the water pollution model is to examine the pollutants and its affect on the biological state of rivers in the SNPBZ in order to better manage the environmental conditions in the area. Main chemical parameters considered in the model are nitrogen and phosphorous. The user may also analyse water quality by evaluating other parameters, either chemical or biological. Different water pollution scenarios can be assessed through the model by operating on different management levers.
Main sources of water pollution analysed in the model are:

a. point sources (civil sources):

- human organic waste (faeces and urine)
- disposed solid waste (burned, buried, littered)

b. diffuse sources:

- agriculture (chemical and organic fertilisers)
- natural sources (forests, rocks, rain).

In particular, this sub-model is conceived and aimed to:

- calculate the potential load of nutrients (Nitrogen, Phosphorus) by different sources of pollution (agricultural fertilisers, civil wastes);
- assess the quality of river water by estimating concentration of nutrients (or other parameters) in the river;
- suggest new management practices and environmentally-sustainable strategies for effective management of water pollution in order to mitigate its impacts on human and ecosystem health.

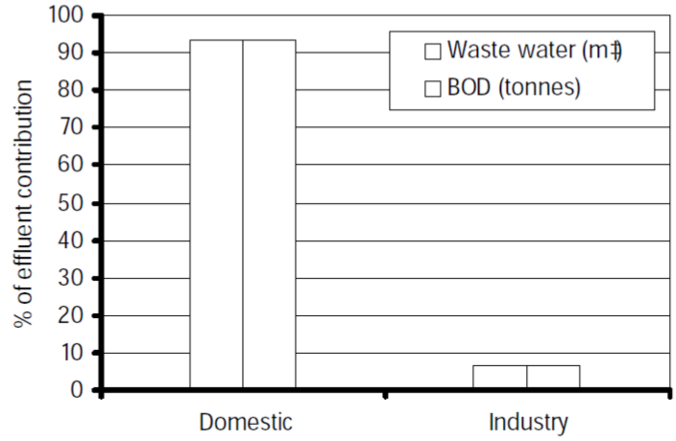
12.2 What is the context in which the model was developed?

Introduction

Although Nepal is rich in water resources, local people are not getting enough quality water to meet their needs. The state of environment report of Nepal (2001) identifies water pollution as the most serious public health issue in Nepal. Human activity is one of the main causes of pollution in drinking water. The causes of water pollution are unprotected water sources, broken sewer lines, discharge of untreated industrial effluent into streams, municipal sewage, urban runoff, agricultural runoff, interrupted water supply, open defecation and garbage disposal in communal areas.

Urban solid waste, domestic effluents and industrial effluents, which are responsible for polluting water and causing waterborne diseases, are disposed mainly in the rivers. Because non-treated wastes are the directly discharged into rivers, all the rivers in Kathmandu Valley have been turned into open sewers. The study of Devkota and Neupane (1994) indicates that about 93% of pollution is from domestic sewage and the remaining 7% from industrial effluents (Figure 13).

Government and semi-government organisations have been directly or indirectly involved in the development, management, conservation and planning of water resources in the country, either through their own efforts or through economic and/or technical assistance from international and bilateral agencies (MOPE, 2001). Realising the importance of ecological, economic and social importance of water resources, various attempts have been made by the government to improve the situation by adopting various development programmes, organisational adjustments and research activities (MOPE, 2001).



Source: Devkota and Neupane (1994)

Figure 13: Domestic and industrial effluent contribution, Kathmandu Valley (1994)

Disposal of human waste is one of the most serious issues in the SNPBZ (Lachapelle, 1995). Improper effluent discharge, human waste and garbage dumping are contaminating water sources along the major trails. Caravello et al (2007) has reported that the water quality of rivers in the Khumbu valley has deteriorated microbiologically as well as chemically.

Many lodge toilets have urine and fecal matter visibly leaking from the toilets. Several of these toilets are located less then five meters from potable water supplies. Many of the toilets store waste at ground level and are therefore prone to leakage during heavy rain periods. Many lodge and public toilets are built on hills and the downhill side of the toilet is open. Heavy rainy periods between July and September can potentially wash out contents of these toilets. Strong sanitation regulation is needed in major population centres to improve village sanitation.

Qualitative analysis of the Water Pollution Model

The first step in overall modeling process adopted under the HKKH Partnership Project has been the qualitative analysis of the socio-ecological system on the basis of existing studies, expert knowledge and stakeholders (Salerno *et al.*, 2009). In this context, a qualitative model on water pollution in the SNPBZ has been developed to describe and analyse current water quality scenario in the park. The qualitative conceptual diagram is shown in Figure 14.

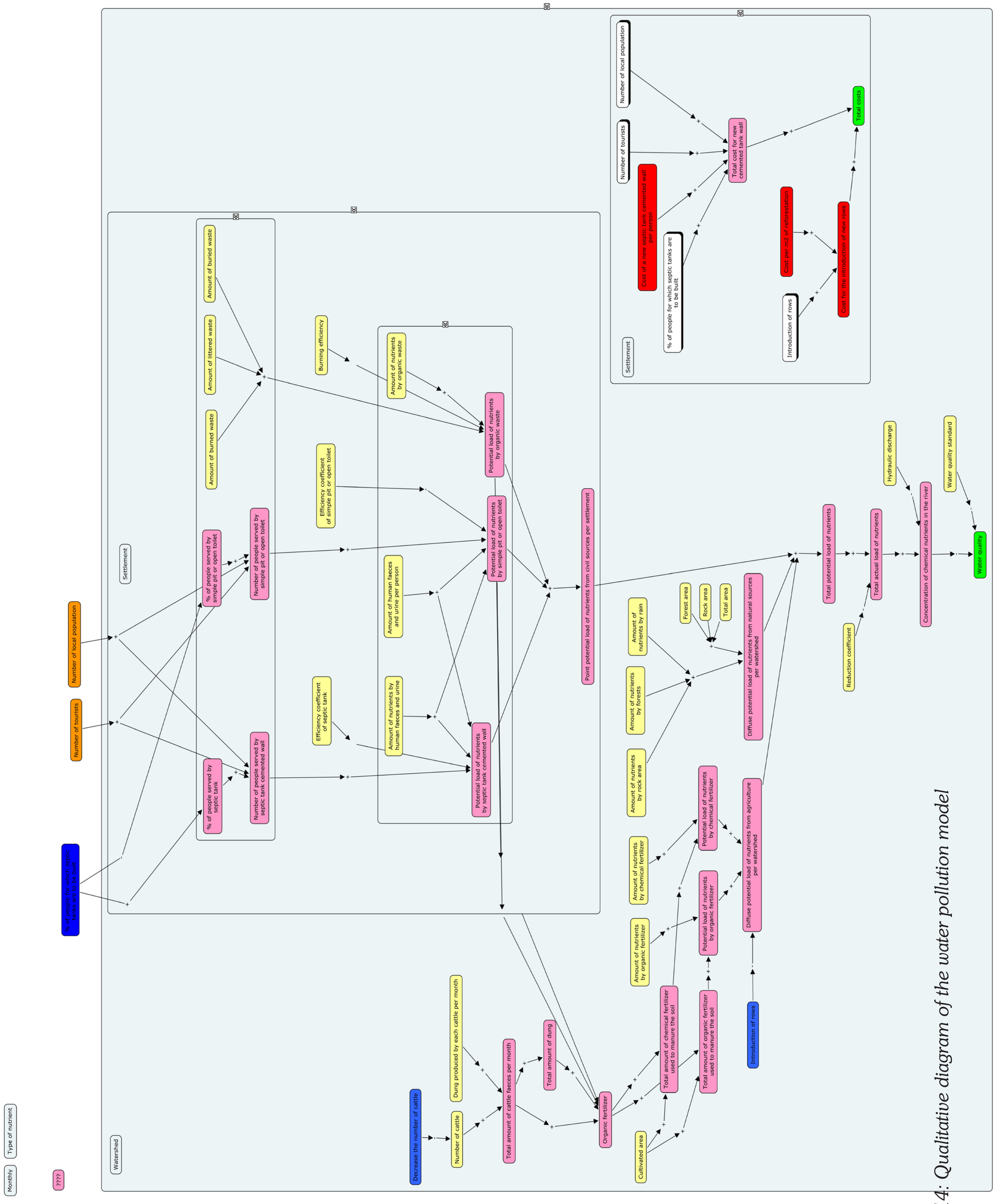


Figure 14: Qualitative diagram of the water pollution model

The sub-model first captures the causal relationship of the potential load of nutrients from both point *(a) point sources (b) diffuses sources of* and then calculates the cost involved in the implementation of management levers (c). The nutrients' load from both point and diffuse sources of water pollution are analysed by the model in order to assess the river water quality on a watershed level (Figure 15). Illustration in blue refers to the management levers applied to this model and the relevant costs (illustrations in red) for these policies are considered as well in the model.

In the qualitative model diagram, civil point sources like human organic waste (faeces and urines) and disposed solid waste (burned, buried, littered) has been identified in SNPBZ.

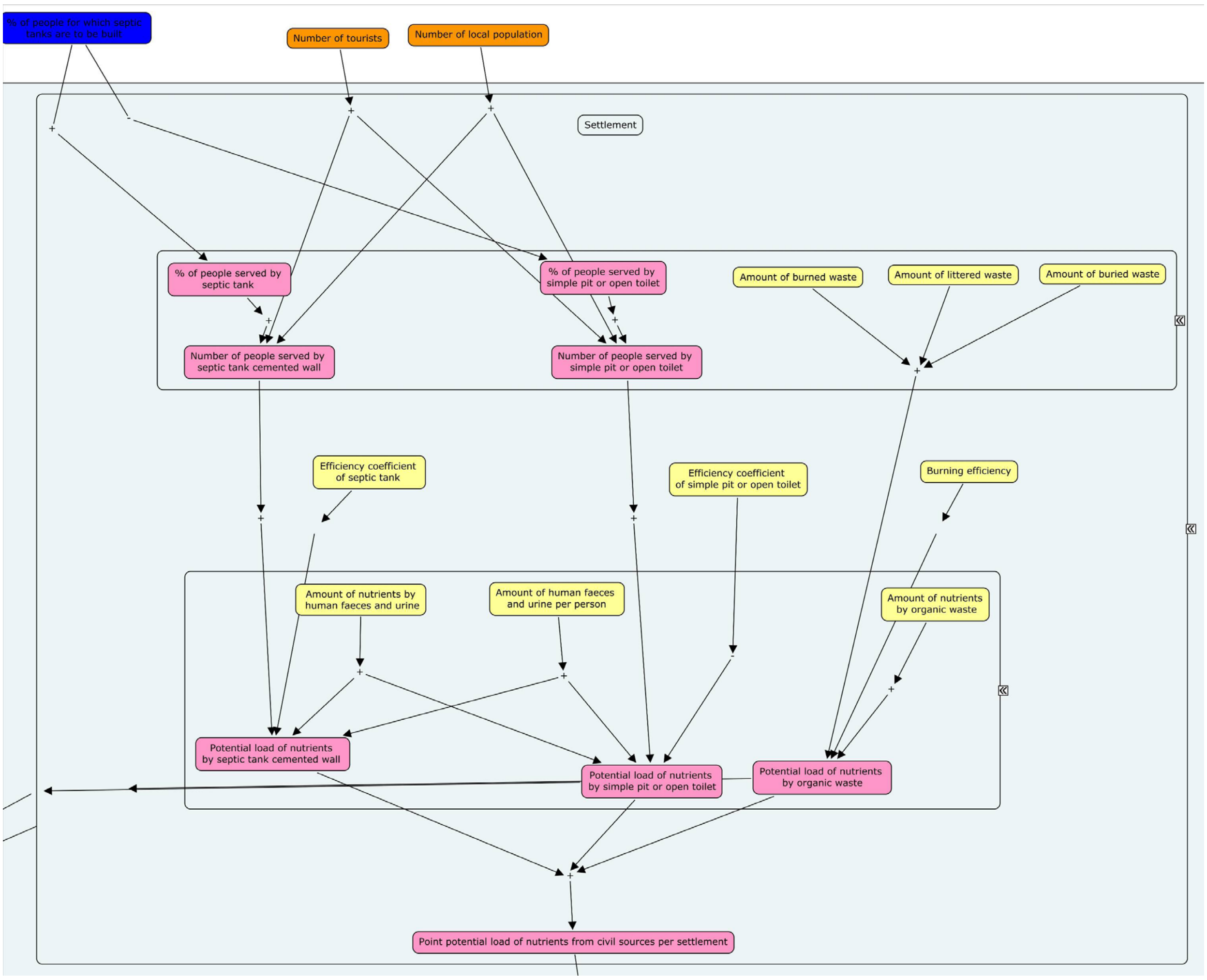


Figure 15: Section of the qualitative diagram of the water pollution model concerning the potential load of nutrients from point sources of pollutants (i.e., civil sources)

The civil load of nutrients from organic waste can be distinguished in relation to the state of toilets and septic tanks. The main typologies of toilet status identified in the park are: with cemented wall septic tanks; stone wall septic tanks, simple pit or open toilets. Following the values of the model, the potential load for each source is calculated through a specific coefficient. Furthermore, for tanks and toilet an efficiency coefficient allows establishing the permeability of the tank. Such type of pollution is calculated for each settlement.

Considering that the aggregation level of the model is per watershed, to measure the total amount of nutrients, the model is run for all the main settlements present in each aggregation level.

The diffuse sources coming from agriculture (chemical and organic fertilisers) and natural sources (forests, rocks, precipitations) are calculated for each watershed with knowledge of the surface of cultivated area, the amount of both chemical and organic fertiliser used as manure and its relevant coefficient specific for each kind of nutrient.

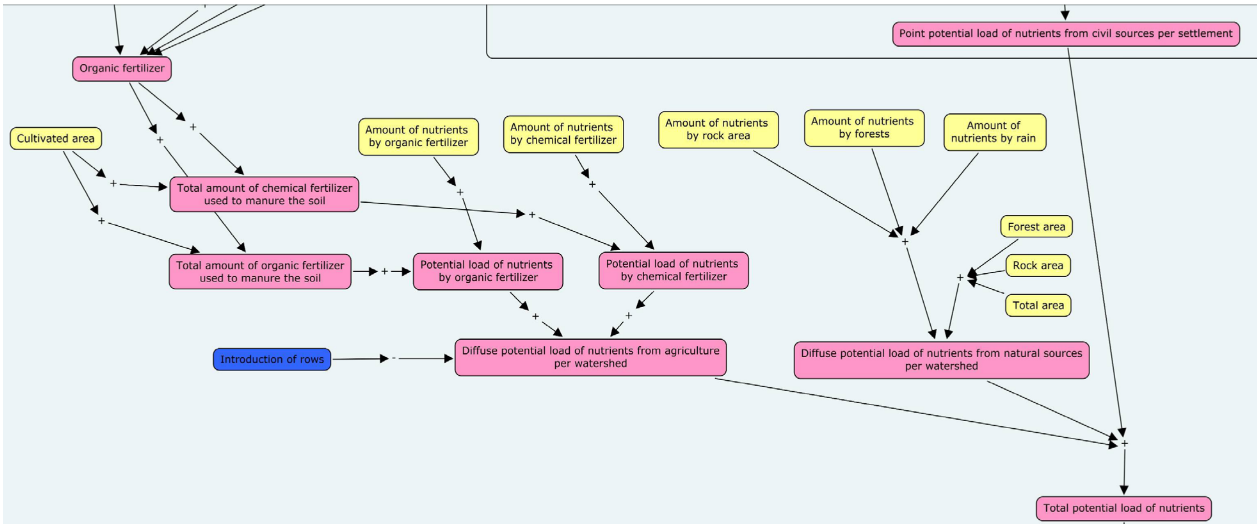


Figure 16: Section of the qualitative diagram of the water pollution model concerning the potential load of nutrients from diffuse sources of pollutants (i.e., agricultural and natural sources)

The *total potential load of nutrients* for each watershed is calculated as sum of the natural, agricultural and civil loads (Figure 17).

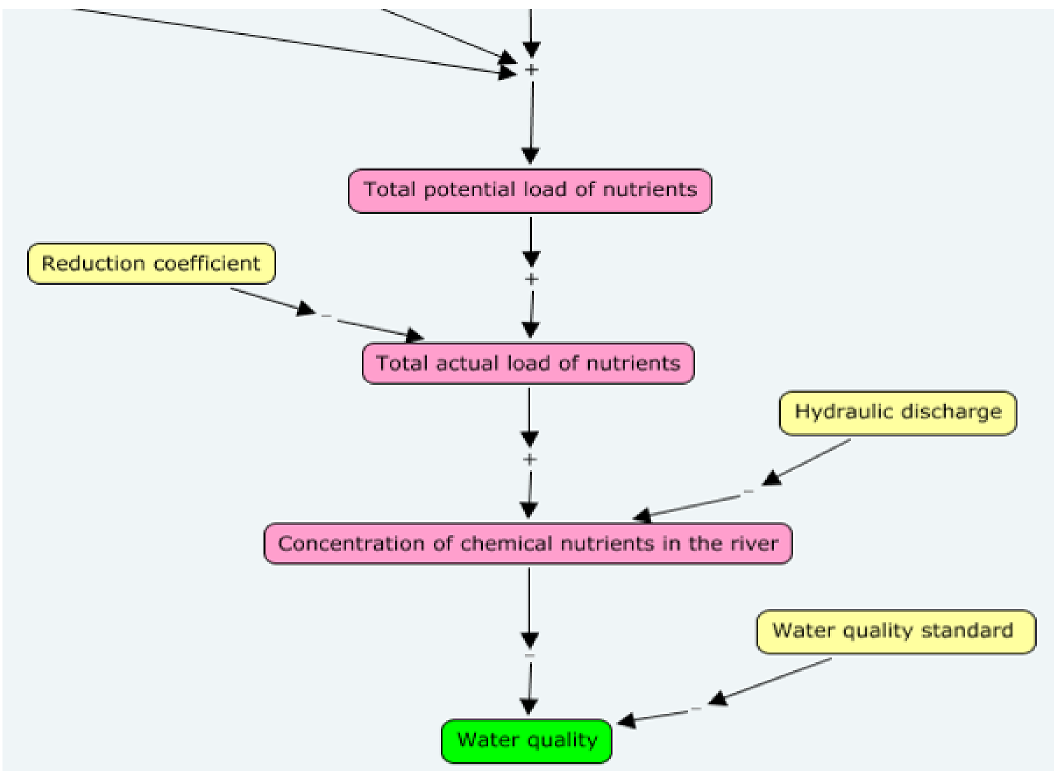


Figure 17: Section of the qualitative diagram of the water pollution model illustrating how to calculate the river water quality from the total potential load of nutrients

As illustrated in Figure 17, by applying a reduction coefficient, the potential load is reduced to obtain the actual load of nutrients that effectively reaches the river. Usually the reduction coefficient can be used coupled with the "distance" factor from the source to the water body. The reduction coefficients should be calibrated indirectly using sampled river data that correspond to different watershed conditions. The calculation of the reduction coefficient is specified in the technical notes.

Considering the water discharge (*hydraulic discharge*) for each watershed, it is possible to obtain the average *concentration of nutrients* for that river section. By comparing the simulated concentration of nutrients with a standard, the water quality of the rivers can be assessed and used to describe the biological condition of the rivers.

Furthermore, the diagram includes an analysis of the costs due to the management policies envisaged in the sub-model that are calculated by each settlement (as shown in Figure 18).

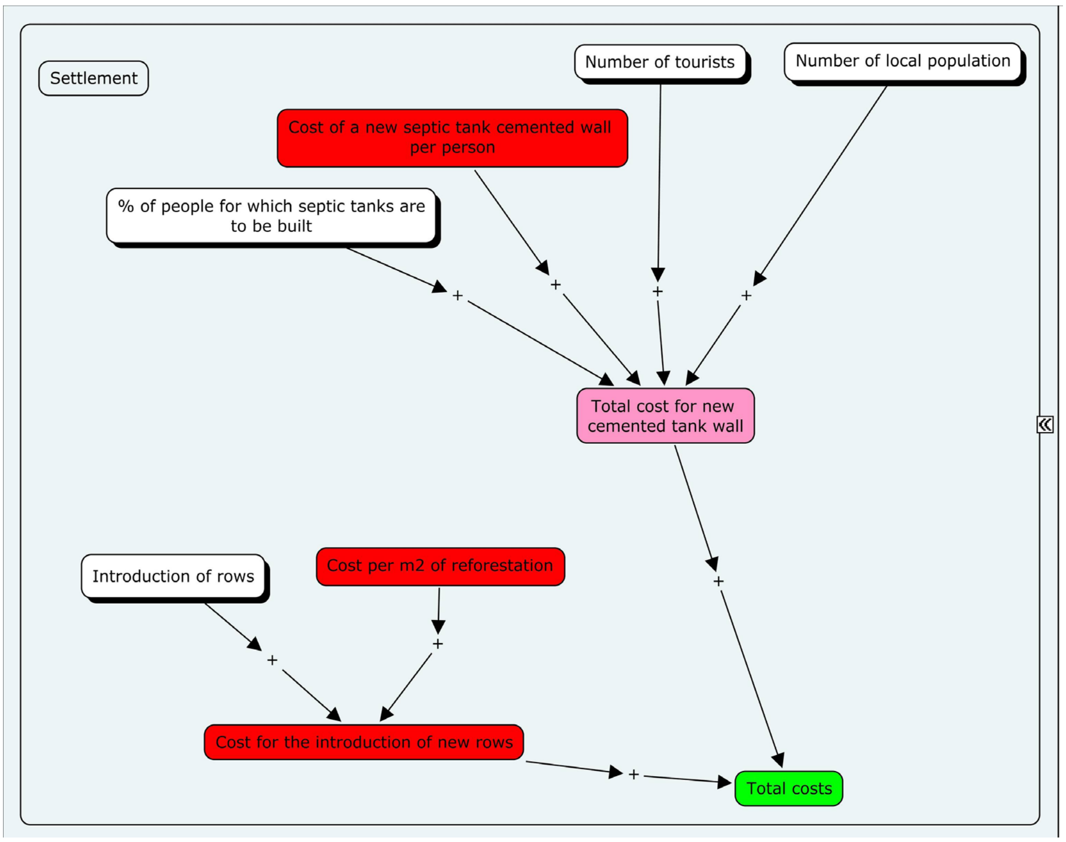


Figure 18: Section of the qualitative diagram of the water pollution model concerning the total costs of all the management policies envisaged

12.3 How does this model work?

In order to interpret the model outputs in a meaningful way, it is essential to have a basic understanding of how this model works and which dynamics it is able to account for.

Starting from the drivers of the system like tourists and local population, and considering the causes of water pollution in the studied area (the SNPBZ in the case study), the model allows to calculate the potential load of nutrients (N, P) by using different coefficient, particularly:

- potential load of nutrients by septic tank
- potential load of nutrients by simple pit
- potential load of nutrients by organic waste
- potential load of nutrients by organic fertiliser
- potential load of nutrients by chemical fertiliser

Using different types of coefficients like those concerning the efficiency of the septic tanks as well as distance between source and river section, the actual load of nutrients reached to the river can be calculated.

Considering both the autodepurative capacity (sink function) of the river as well as its water discharge, the concentration of nutrients in the river can be estimated and the river status (i.e., the water quality) can be evaluated by comparing the concentration of nutrients in the river with national (e.g., Nepalese) relevant standard parameters.

By changing some management levers, it is possible to see the effects of each policy on the indicators of performance, which are the total cost of the policy levers and water quality status. The costs due to different management policy levers applied in the model are analysed too.

The model considers five watersheds identified in SNPBZ along with 18 settlements similar to other models.

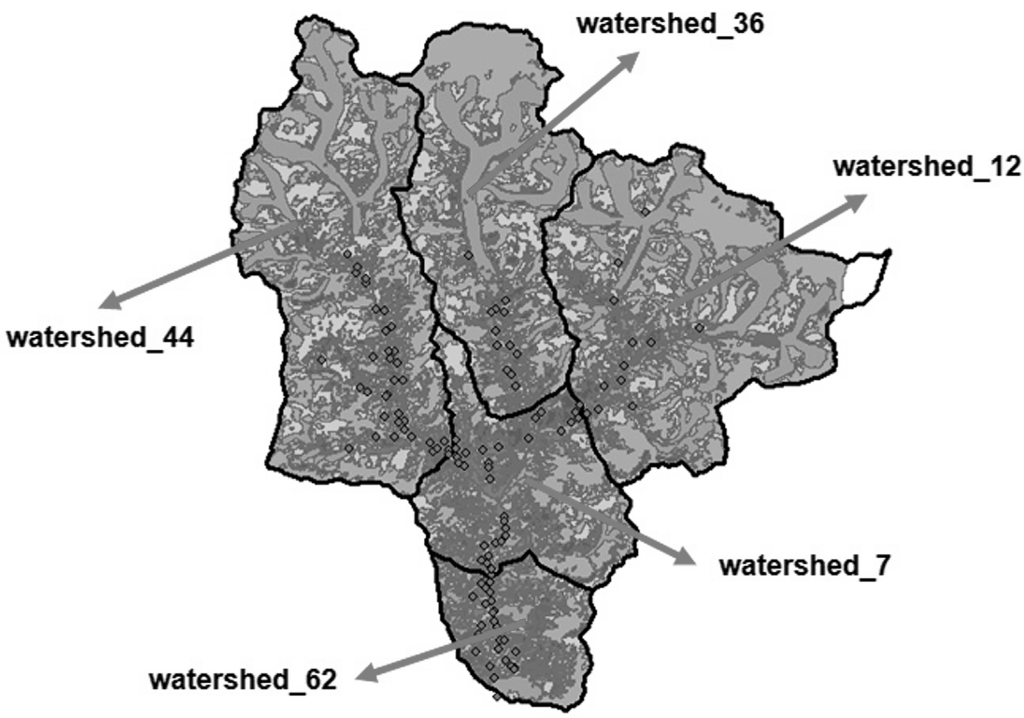


Figure 19: Watersheds in SNPBZ. Each watershed is identified by a code as follows: 1=watershed_44, 2= watershed_36, 3= watershed_12, 4= watershed_7, 5= watershed_62

12.4 The model inputs

The water pollution model includes six kinds of input data or input variables that are connected with an input table in *.csv file format as indicated in Table 68:

Table 68: Input variables and correlated input table.csv files of the water pollution model

Input variable/s	Input table (*.csv format)
SETTLEMENT DATA	data_water_settlement.csv
WATERSHED DATA	data_water_watershed.csv
NUTRIENTS DATA	data_water_nutrients.csv
HYDRAULIC DISCHARGE [m3/s]	discharge_grid.csv
REDUCTION COEFFICIENT [No.] STANDARD WITHOUT ANTHROPIC IMPACT [No.]	*reduction_coefficient.csv*
CONNECTS [true or false]	watershed.csv

A brief description of each input table is provided below. An example of each table is also furnished with input data specifics for the SNPBZ case study. However, users can provide their own input data for the area of study simply by editing (or replacing) the current value.

Data_water_settlement.csv

The *data_water_settlement.csv* input table contains data (input variables) on the selected settlements. Particularly, the table is composed of nine columns concerning:

- *Settlement* [Name]
- *Watershed_n* [No]: number representing the watershed belonging to each settlement
- *Watershed* code [No]: number representing the GIS-code of each watershed
- *Watershed ID* [Name]
- *Amount of buried waste* [Kg/month]: amount of domestic buried waste each month in each settlement
- *Amount of burned waste* [Kg/month]: amount of domestic burned waste each month in each settlement
- *Amount of organic littered waste* [Kg/month]: amount of domestic organic littered waste each month in each settlement
- *initial percentage* [%]: initial percentage of people served by septic tank
- *Average cost of septic tank* [currency]: average cost to introduce septic tank per person (SNPBZ cost are expressed in Nepalese Rupees per month (NRs/person*month)

Table 69: Example of data_water_settlement.csv input table for SNPBZ

Settlement	Initial percentage	Amount of domestic organic waste burned (kg/month) WP13	Amount of domestic organic waste buried (kg/month) WP14	Amount of domestic organic waste littered on the soil (kg/month) WP15	Average cost of septic tank NRs/person*month	Watershed code	watershed ID	watershed_n
Chukung	61.35714	4052.929	2382.219	117.6429	110	0	watershed id	0
Dole	33	636	908.25	36	140	36	watershed_36	2
Dingboche	83	6879	9827.4	393	140	12	watershed_12	3
Dzonglha	61.35714	4052.929	2382.219	117.6429	110	0	watershed id	0
Gokyo	71	754	1076.625	43	140	36	watershed_36	2
Gorakshep	100	273	389.7	16	140	12	watershed_12	3
Khumjung	25	6980	1495.729	100	80	7	watershed_7	4
Lobuche	100	337	480.795	19	140	12	watershed_12	3
Lukla	75	12293	768.3154	154	80	62	watershed_62	5
Machherma	61.35714	4052.929	2382.219	117.6429	110	0	watershed id	0
Marlung	61.35714	4052.929	2382.219	117.6429	110	0	watershed id	0
Namche	63	17450	2492.837	249	80	7	watershed_7	4
Pangboche	41	1976	2823.15	113	140	7	watershed_7	4
Phakding	80	1102	1574.245	63	80	7	watershed_7	4
Pheriche	64	903	1289.7	52	140	12	watershed_12	3
Phortse	30	3113	4446.45	178	80	7	watershed_7	4
Tengboche	31	341	486.99	19	80	7	watershed_7	4
Thame	63	3704	5290.875	212	80	44	watershed_44	1

Data_water_watershed.csv

The *data_water_watershed.csv* input table is composed of seven columns containing specific data for each selected watershed, respectively, indicating:

- *Watershed* [code]
- *Cultivated area* [m2]
- *Forest Area* [m2]
- *Rock Area* [m2]
- *Other POP* [No] (where POP= population)
- *Total Area* [m2]
- *Chemical fertilizer* [Kg/m2*month]

Table 70: Example of data_water_watershed.csv input table for SNPBZ

Watershed [code]	Cultivated area [m2]	Forest Area [m2]	Rock Area [m2]	Other POP [No.]	Total Area [m2]	Chemical fertiliser [Kg/m2*month]
44	2657475	68681925	3.04E+08	183	3.8E+08	0
36	639450	39274425	2.85E+08	20	2.74E+08	0
12	980775	55719000	1.88E+08	40	3.72E+08	0
7	2330325	1.08E+08	1.89E+08	896	1.77E+08	0
62	2553750	80329275	30935700	872	98000000	0

Data_water_nutrients.csv

The *data_water_nutrients.csv* input table deals with contribution in terms of chemical or biological parameter considered (N-NO_3, P-PO_4, TN, TP, generic, where generic may indicate also a biological parameter settled by the user) provided by different sources (forests, rocks, chemical and organic fertilizers, human faeces and urine, organic waste).

The input table is composed of nine columns indicating:

- *Nutrients* [Name]: indicates the chemical parameter (N-NO3, P-PO4, TN, TP, generic, where “generic” may indicate also a biological parameter) that is considered in the model;
- *rock area* [mg/m2*month]: indicating the amount of chemical parameter per unit surface of rock area;
- *forest* [mg/m2*month]: amount of selected chemical parameter per unit surface of forest area;
- *rain* [mg/m2*month]: amount of selected chemical parameter per unit surface of rain;
- *chemical fertiliser* [gm/Kg]: amount of selected chemical parameter per Kilogram of chemical fertiliser;
- *organic fertiliser* [gm/kg]: amount of selected chemical parameter per Kilogram of organic fertiliser;
- *human faeces and urine* [gm/kg]: amount of selected chemical parameter per Kilogram of human faeces and urine;
- *organic waste* [gm/kg]: amount of selected chemical parameter per Kilogram of organic waste;
- *burning efficiency* [No]: efficiency of the burning process and may assume values from 0 (bad efficiency) to 1 (best efficiency);
- *row reduction* [%]: the percentage of reduction due to the introduction of new row.

Table 71: *Example of data_water_nutrients.csv input table for SNPBZ*

Nutrients	rock area [mg/m2* month]	forest [mg/ m2* month]	rain [mg/ m2* month]	chemical fertilizer [gm/Kg]	organic fertilizer [gm/kg]	human faeces and urine [gm/ kg]	organic waste [gm/kg]	burning efficiency [No]	Row reduction [%]
N-NO3	0.5634	1.53	0.0021	460	10.3	15	1.5	1	80
P-PO4	0.0093	0.043	0	0	6.7	5.3	1	0	60
TN	0	0	0	0	0	0	0	0	0
TP	0	0	0	0	0	0	0	0	0
generic	0	0	0	0	0	0	0	0	0

Discharge_grid.csv

The *discharge_grid.csv* input table regards the average daily hydraulic discharge [m^3/s] of the river in the watershed end point per each considered watershed. An example of input table for five watersheds in the SNPBZ is provided in Table 72:

Table 72: Example of discharge_grid.csv input table for SNPBZ.
Months are indicated in the time/index 1 column

Time \ Index 1	1	2	3	4	5
1	0.16	0.119	0.16	0.693	1.037
2	0.147	0.1	0.138	0.715	1.309
3	0.658	0.559	0.75	2.609	3.16
4	0.943	0.788	1.056	3.758	4.639
5	1.152	0.913	1.223	4.703	6.221
6	3.127	2.513	3.366	12.672	16.432
7	9.487	8.223	11.037	37.486	44.576
8	9.276	7.867	10.548	36.816	44.721
9	3.106	2.526	3.384	12.512	15.962
10	0.7	0.55	0.737	2.872	3.847
11	0.058	0.043	0.058	0.254	0.384
12	0.029	0.018	0.026	0.168	0.399

Reduction_coefficient.csv

The *reduction_coefficient.csv* input table is composed of six columns, where the input variables are particularly:

- *Watershed ID* [Name]
- *Watershed_n* [No.]
- *Chemical parameters* [Name]: indicates the chemical parameter (N-NO3, P-PO4, TN, TP, generic, where "generic" may indicate also a biological parameter) that is considered in the model
- *Chemical parameter index* [No.]: number identifying each chemical parameter (where: N-NO_3= 1, P-PO_4=2, TN =3, TP = 4, generic=5)

- *reduction coefficient* [No.]: average experimental reduction coefficient
- *standard concentration* [No.]: average standard concentration of chemical elements without considering anthropic impact

An example of input table for the SNPBZ is provided in Table 73 below, considering five watersheds.

Table 73: Example of reduction_coeffcient.csv input table for SNPBZ

Watershed ID	Watershed_n	Chemical parameters	Chemical parameters index	Reduction coefficient	Standard concentration
watershed_44	1	N-NO3	1	0.751398	5
watershed_44	1	P-PO4	2	0.628687	0.24
watershed_44	1	TN	3	0	0
watershed_44	1	TP	4	0	0
watershed_44	1	generic	5	0	0
watershed_36	2	N-NO3	1	0.619561	5
watershed_36	2	P-PO4	2	0.917734	0.24
watershed_36	2	TN	3	0	0
watershed_36	2	TP	4	0	0
watershed_36	2	generic	5	0	0
watershed_12	3	N-NO3	1	0.751398	5
watershed_12	3	P-PO4	2	0.628687	0.24
watershed_12	3	TN	3	0	0
watershed_12	3	TP	4	0	0
watershed_12	3	generic	5	0	0
watershed_7	4	N-NO3	1	0.751398	5
watershed_7	4	P-PO4	2	0.628687	0.24
watershed_7	4	TN	3	0	0
watershed_7	4	TP	4	0	0
watershed_7	4	generic	5	0	0
watershed_62	5	N-NO3	1	0.551178	5
watershed_62	5	P-PO4	2	0.479835	0.24
watershed_62	5	TN	3	0	0
watershed_62	5	TP	4	0	0
watershed_62	5	generic	5	0	0

Watershed.scv

The *watershed.csv* input table concerns input variable namely *connects* that assesses whether each watershed is or not [true or false] a sub-watershed (*upstream_n*) of a bigger one (*downstream_n*). For instance, the biggest watershed is affected by potential load of all the upstream watersheds included. Therefore, the model aggregates nutrient potential loads considering this aspect.

The input table is composed of five columns indicating:

Table 74: Example of watershed.csv input table for SNPBZ

downstream	downstream_n	Upstream	upstream_n	connects
watershed_12	3	watershed_12	3	true
watershed_12	3	watershed_36	2	false
watershed_12	3	watershed_44	1	false
watershed_12	3	watershed_62	5	false
watershed_12	3	watershed_7	4	false
watershed_36	2	watershed_12	3	false
watershed_36	2	watershed_36	2	true
watershed_36	2	watershed_44	1	false
watershed_36	2	watershed_62	5	false
watershed_36	2	watershed_7	4	false
watershed_44	1	watershed_12	3	false
watershed_44	1	watershed_36	2	false
watershed_44	1	watershed_44	1	true
watershed_44	1	watershed_62	5	false
watershed_44	1	watershed_7	4	false
watershed_62	5	watershed_12	3	true
watershed_62	5	watershed_36	2	true
watershed_62	5	watershed_44	1	true
watershed_62	5	watershed_62	5	true
watershed_62	5	watershed_7	4	true
watershed_7	4	watershed_12	3	true
watershed_7	4	watershed_36	2	true
watershed_7	4	watershed_44	1	true
watershed_7	4	watershed_62	5	false
watershed_7	4	watershed_7	4	true

Slider inputs:

A number of variables have been introduced in the model as a slider input that means the slider allows entering single data value in the model within certain range. For instance,

- Efficiency coefficient of septic tank [%]
- Efficiency coefficient of simple pit [%]
- Number of cattle [No]
- Dung produced by each cattle per month [Kg]
- Percentage of faeces used for dung [%]
- Percentage of faeces used for manure [%]
- Percentage of reduction from wet faeces and dry dung [%]
- Percentage of organic waste used as manure [%]
- People producing waste [No]

12.5 Management levers

The management levers were developed in collaboration with local and national stakeholders and experts to ensure that they reflect viable options for improving the management of SNPBZ that are worthwhile to explore by means of simulating hypothetical scenarios. In fact, the user can operate on the model inputs to simulate different scenarios by changing the applied management levers.

The effect of user-defined management lever settings on system can be assessed by looking at the changes of system "performance indicators" over time. The performance indicators are explained in detail in the next section.

The management levers applied to this model are designed to affect the following dynamics of the model:

1. **% of people for which septic tanks are to be built**: inserting a value from 0 to 100 the user can simulate the effects of preventing leakage of fecal matter (human waste) into surface water bodies and groundwater, a main cause for water contamination. The user can see the effects of this policy lever on the indicators of performance: water quality indexes (N-NO3, P-PO4, TN, TP, generic) and the total cost of the policies. When a user changes this percentage, a value from 0 to 100, the model directly changes the variables representing the percentage of people served by stone walled septic tank, simple pit and open toilets.

2. **Decrease the number of cattle**: inserting a value from 0 to 100, the user can simulate the effects of improving the potential load of nutrient to the river through each watershed. The decrease in the livestock results in the decreased production of the dung with less quantity of nutrient in the land. The user can see the effects of this policy lever on the indicators of performance: water quality indexes (N-NO3, P-PO4, TN, TP, generic) and the total cost of the policies. The management lever directly treats the reduction of the total amount of faeces per month.

3. **Introduction of rows**: inserting a value of 0 and 1, the user can simulate the effects of the introduced rows in the field. The user can see the effects of this policy lever on the indicators of performance: water quality indexes (N-NO3, P-PO4, TN, TP, generic) and the total cost of the policies. When a user keeps value 0, it indicates no entry of this lever.

The following table lists these management levers schematically and provides information on the way the values for the management levers can be set. It shows the minimum and maximum value of the management lever and its type: whether it requires an integer (int) or real value (real) to be defined and the unit of the lever.

Table 75: Policy levers for the water pollution model, including specifications and connected variables

Policy Lever Name	Specification	Variable/s name	Unit and Description
Policy_lever_ Introduction of rows	Introduction of tree rows on one side of the cultivated area reduces the flow of nutrient load to river section absorbing the significant amount of nutrients by the tree species. This will prevent flow of nutrient from agriculture land to water body reducing potential load of nutrient in the water.	Introduction of rows	[0, 1], int The value is 0 if the policy is not applied, but is 1 it is applied.

Policy_lever_septic tank	It represents percentage of people that want a new septic tank. Along the trekking routes, a significant number of tea shops and a few hotels are not equipped with a septic tank. Many houses only have simple pits or stone walled septic tanks. Leaking of faecal matter (human waste) into surface water bodies and groundwater is a major source of water contamination. The management lever minimises the contamination of surface runoff water from simple pit, open toilets during the rainy season.	% of people for which septic tanks are to be built	[0,100], int, [%] This value represents the percentage of people for which septic tanks are to be built.
Policy_lever_ decrease of number of livestock	The lever represents percentage decrease of the amount of cattle in the park. One of the current concerns on contribution of nutrient load to land area is littering of cattle dung and use of dung as a fertiliser in the cultivated area that ultimately concentrates in the river waters. So, the management lever is to reduce the cause of littered dung.	Decrease the number of cattle	[0,100], int, [%] This value represents the percentage of decrease of cattle.

12.6 The model outputs

The model provides different outputs that include both the model performance indicators as well as other intermediate variables described hereafter. By operating on management levers of the model, the user can evaluate their effects on those outputs and obtain possible scenarios on the water quality condition in the studied area.

Indicators of performance

The model outputs will tell user the "performance of the system" based on the management lever-values selected before running the model. By means of interpreting the values of the performance indicators for a simulation, the user will obtain information about the potential positive or negative effects of chosen management option (management lever settings). Again, performance indicators have been developed in collaboration with local and national stakeholders and experts and reflect key system dynamics of high relevance for managers.

The performance indicators used in the model are:

- ✓ POTENTIAL LOAD OF NUTRIENTS PER SETTLEMENT
- ✓ WATER QUALITY: represents an index that show the quality of the river according to the chemical parameter/s considered in the river (N-NO_3, P-PO_4, TN, TP, generic parameter). River conditions are good if the index is around 1, meaning that there are only natural loads of selected chemical parameter. The increased index value indicates the decreased water quality condition from the natural state.
- ✓ TOTAL COST: the implementation of management levers is associated with financial cost. As in reality, extent to which management options are put into practice has an effect on the overall budget required. In the model, this means that the cost involved to implement a management option is dependent on the value chosen for a management lever. This indicator simply sums up the cost for all management levers as set by the user. If no management action is taken, all management levers set to 0. This indicator will be 0 and the model will run based on a "business as usual" scenario.

All these outputs can be exported as a table composed of records for each month and which includes columns as reported by each different output.

Table 76: Output table of the POTENTIAL LOAD OF NUTRIENTS PER SETTLEMENT

Name									
Index 1	Chukung				Dole				…
Time \ Index 2	1	2	…	5	1	2	…	5	…
0	1.2285e+006	2.0020e+006	…	0	1.6007e+006	889502.0285	…	0	…
1	1.2285e+006	2.0020e+006	…	0	1.6818e+006	918157.3408	…	0	…
2	1.8000e+006	2.2040e+006	…	0	3.3849e+006	1.5199e+006	…	0	…
3	2.1637e+006	2.3325e+006	…	0	4.3581e+006	1.8638e+006	…	0	…
…	…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…	…
11	…	…	…	…	…	…	…	…	…

Table 77: Output table of the WATER QUALITY

Name	WATER QUALITY												
Index 1	1				2				…	…			
Time \ Index 2	1	2	…	5	1	2	…	5	…	1	2	…	5
0	0.2541	1.3362	…	0	0.1635	0.0984	…	0	…	…	…	…	…
1	0.2766	1.4542	…	0	0.1948	0.1174	…	0	…	…	…	…	…
2	0.0622	0.3269	…	0	0.0354	0.0218	…	0	…	…	…	…	…
3	0.0436	0.2292	…	0	0.0254	0.0159	…	0	…	…	…	…	…
…	…	…	…	…	…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…	…	…	…	…	…
11	…	…	…	…	…	…	…	…	…	…	…	…	…

Table 78: Output table of the TOTAL COST for SNPBZ

Name			
Time \ Index 1	Chukung	Dole	…
0	0	0	…
1	0	0	…
2	0	0	…
3	0	0	…
…	…	…	…
…	…	…	…
11	…	…	…

Other outputs

Besides the aforementioned performance indicators, other outputs provided by this model are the following intermediate variable:

- ✓ CONCENTRATION OF CHEMICAL NUTRIENTS IN THE RIVER

This output can be exported as a table composed of records for each month and which includes columns as reported in Table 79.

Table 79: Output table of the CONCENTRATION OF CHEMICAL NUTRIENTS IN THE RIVER Intermediate variable for SNPBZ

Name	CONCENTRATION OF CHEMICAL NUTRIENTS IN THE RIVER												
Index 1	1				2				…	…			
Time \ Index 2	1	2	…	5	1	2	…	5	…	1	2	…	5
0	1.2706	0.3207	…	0	0.8176	0.0236	…	0	…	…	…	…	…
1	1.3831	0.3490	…	0	0.9739	0.0282	…	0	…	…	…	…	…
2	0.3108	0.0784	…	0	0.1772	0.0052	…	0	…	…	…	…	…
3	0.2178	0.0550	…	0	0.1271	0.0038	…	0	…	…	…	…	…
…	…	…	…	…	…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…	…	…	…	…	…
11	…	…	…	…	…	…	…	…	…	…	…	…	…

12.7 Bibliography

Caravello G.U., A. M. Boselli, P. Bertollo and A. Baroni, 2003. *Assessing ecosystem health: an analysis of tourism related change and impact in Khumbu valley (Nepal)*. Environmental Medicine and Public Health Department, Padova University (Italy).

Devkota, S.R. and C.P. Neupane. 1994. *Industrial Pollution Inventory of the Kathmandu Valley and Nepal.* Kathmandu: Industrial Pollution Control Management Project, HMG/MOI/UNIDO/91029

Jha, P. K. 2009. *Impact of tourism on water quality in Sagarmatha National Park, Nepal*. Field research report submitted to Ev-K2-CNR under HKKH Partnership Project. Central Department of botany, Tribhuvan University, Kirtipur, Kathmandu.

Lachapelle P., 1995. *A report on human waste management in Sagarmatha National Park*. University of Vermont Burlington, VT & School for International Training, Kathmandu, Nepal.

MOPE. 2002. *State of the Environment*, 2001. Ministry of Population and Environment (MOPE), Kathmandu, Nepal.

Pagnotta, R. and G. Barbiero. 2003. Stima dei carichi inquinanti nell’ambiente marino-costiero. Ann. Ist. Sup. Sanità, 39:3-10.

Running Tourism and Population Dynamics Model

The system dynamics models developed by the HKKH Partnership project have been explained in detail in the previous chapters. Of the seven models developed by the project, Tourism model and Population Dynamics model have been developed to run on a daily basis whereas the other five remaining models have been developed to run on a monthly basis. Based on these time steps, the HKKH Partnership project has developed the following two composite models:

- Tourism and Population Dynamics Model
- Solid Waste, Energy, Indoor Air Pollution, Water Pollution and Forestry Composite Model

The DST runs these models using Simile Scripting feature of Simile software. Therefore in order to run these models in DST, it is necessary that the user has at least a free evaluation edition of Simile software installed in their machines.

This section provides step-by-step instructions on how to run Tourism and Population Dynamics Model in DST. The steps to run the second composite model are provided in the next section.

As the name suggests, the Tourism and Population Dynamics Model has been developed by combining the Tourism model and Population Dynamics model together with the connection between two individual models clearly defined within the composite model. This composite model, in the form of "tourism and population.sml" file, is stored in the user's computer at:

..\Scenario Analysis\System Dynamic Models\SimileModels\CompositeModels

and all the corresponding input data are stored in:

..\Scenario Analysis\System Dynamic Models\SimileModels\CompositeModels\Tourism data

A model specific Graphic User Interface (GUI), in the form of **Tourism and Population Model** dialog, has been provided in the DST software to allow users to set the policy levers and run the Tourism and Population Model in a user-friendly manner.

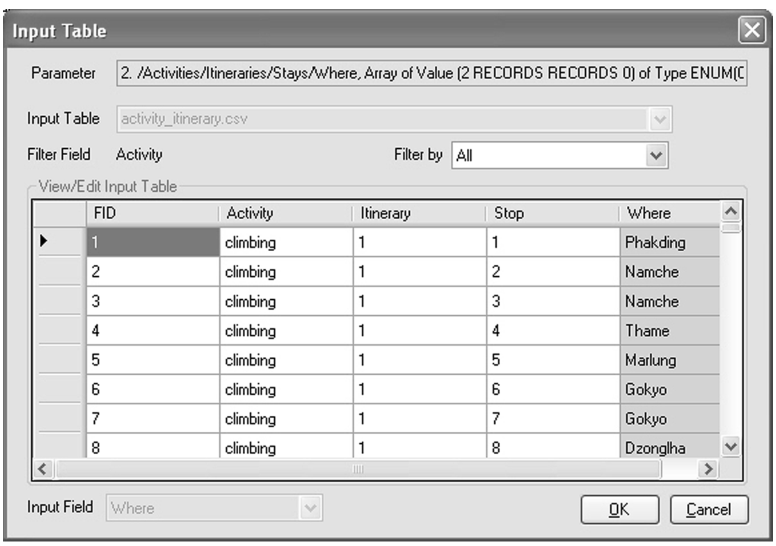
Please refer to Tourism Model and Population Dynamics Model sections for detailed information on all the input, output and policy lever variables.

- Click **Scenario Analysis** menu.
- Click **Tourism and Population** sub-sub-menu under **System Dynamic Models** vertical sub-menu. This will open a **Tourism and Population Model** dialog and also add settlement point layers, besides other GIS layers, to **Spatial Analysis** module.

Data Parameters

The **Data Parameters** tab under **Tourism and Population Model** dialog lists all the input variables for Tourism and Population Model and allows users to view the data assigned to the model input variables.

- Click **View/Edit** next to the variable of your interest to see the corresponding data related to that variable. An **Input Table** dialog is opened to show the corresponding data for that variable. For example, click **View/Edit** next to "/Activities/Itineraries/Stays/Where" to view or edit input data for Where variable.



- Select climbing or trekking under **Filter by** drop-down to filter the data based on activity.

Although the system allows users to modify the input data, it is advisable to use this interface just to view the input data and not modify it since the modification of data in an inappropriate manner may have adverse effects in model output.

- Click **Cancel** to close the **Input Table** dialog without saving any changes.
- Change the input values in the **Input Table** dialog and click **OK** to save the changes close this dialog.

Policy Levers

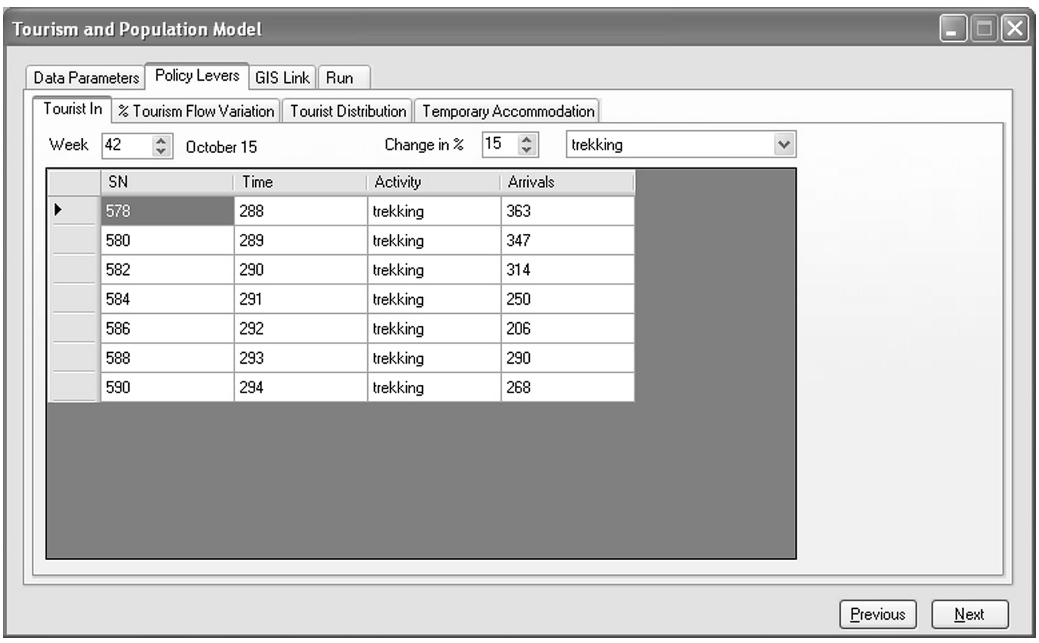
There are three different sets of policy levers considered in the Tourism and Population model:

Spreading visitor flows over time

Change in percentage of tourists flow in a given week

This allows changing the flow of tourists to SNPBZ for selected weeks.

- If necessary, click **Next** to go to **Policy Levers** tab in **Tourism and Population Model** dialog.
- Select **Tourist In** sub-tab.
- Set the week of your interest in the **Week** drop-down. Notice that the starting day of that week is displayed next to it.

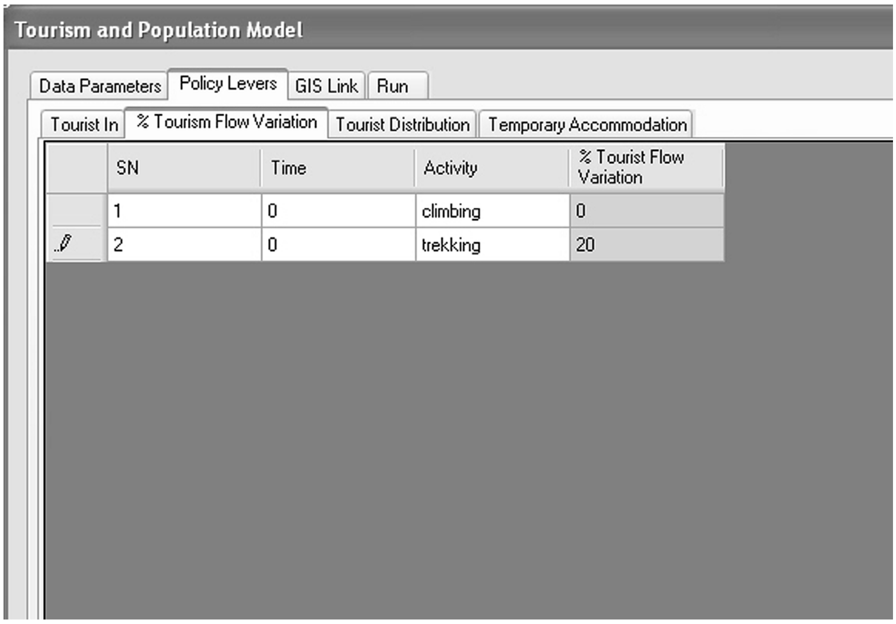


- Set the percentage of increase or decrease for the **trekking** activity for that week in **Change in %**.
- Press Return or Enter key on the keyboard. Notice that the Arrivals values are updated accordingly.
- Similarly, choose **climbing** activity and set the percentage of increase or decrease for the climbers in **Change in %**.
- Repeat the above steps to change the percentage of tourists going to SNPBZ for other weeks.

Percentage of tourist flow variation

It allows changing the percentage of tourists entering SNPBZ for the whole year for trekking and climbing activities.

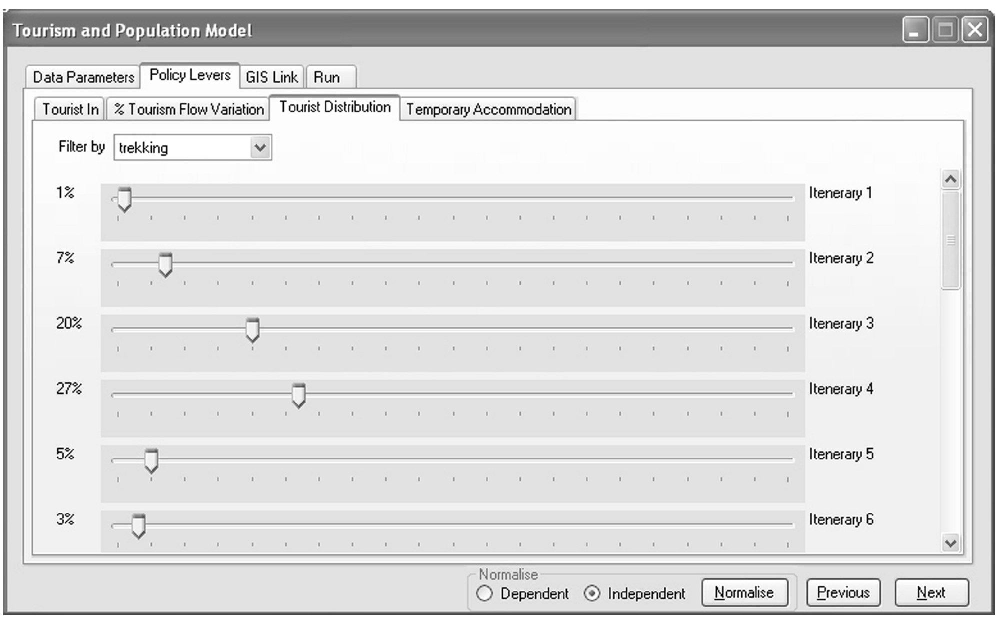
- Click **% Tourism Flow Variation** sub-tab.
- Under **% Tourism Flow Variation** column, type in the percentage of increase or decrease of tourists going to SNPBZ for climbing and trekking activities.



Tourist Distribution

This management lever refers to changing the proportion of tourists going to 20 given itineraries for climbing or trekking activity. Please refer to Tourism model for detailed information on these 20 itineraries.

- Click **Tourist Distribution** sub-tab. Notice that trekking activity is selected under **Filter by** drop-down and **Independent** is selected under **Normalise** option-group by default.

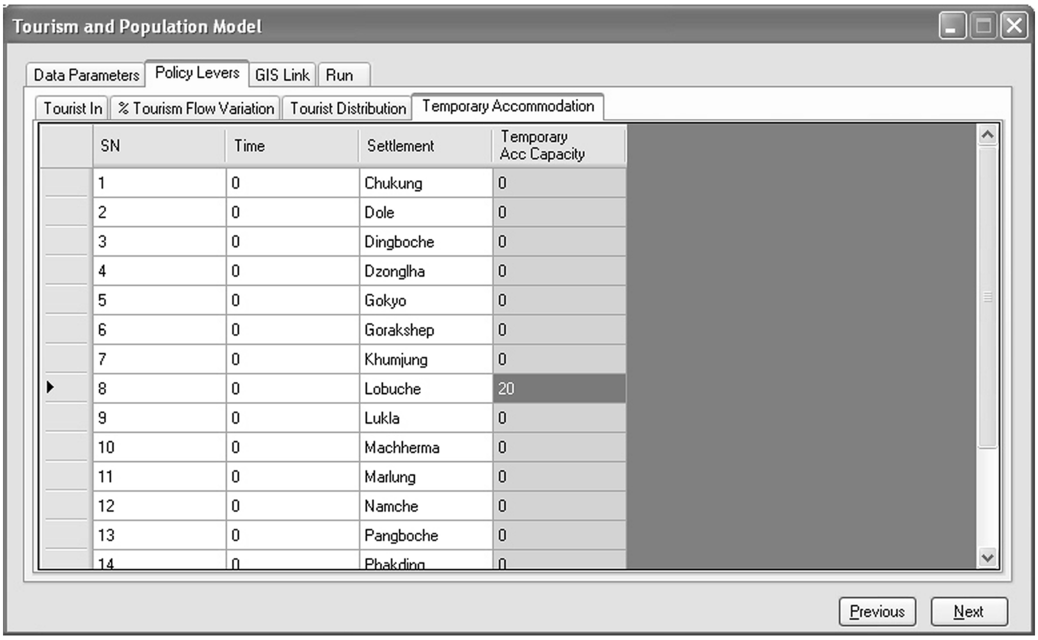


- The sliders show default proportion values for different itineraries. Change the proportion values for itineraries of your interest by dragging the sliders of those itineraries.
- Click **Normalise** to normalise the values so that sum of the proportion of all the itineraries becomes 100%.
- Alternatively, select **Dependent** under **Normalise** option-group. Next, drag a slider of the itinerary of your interest to set an appropriate value. Notice that other sliders will change automatically so that sum of the percentage of all the itineraries becomes 100%.
- Similarly, select climbing activity under **Filter by** drop-down and change the distribution of over 20 different itineraries for this activity if necessary.

Temporary Accommodation

This policy lever allows adding temporary accommodation capacity of given settlements in terms of percentage.

- By default, the temporary bed capacities for each of the settlements are set to 0. In order to increase the temporary bed capacity of a settlement, type a percentage of increase in bed capacity for that settlement under **Temporary Acc Capacity** column.

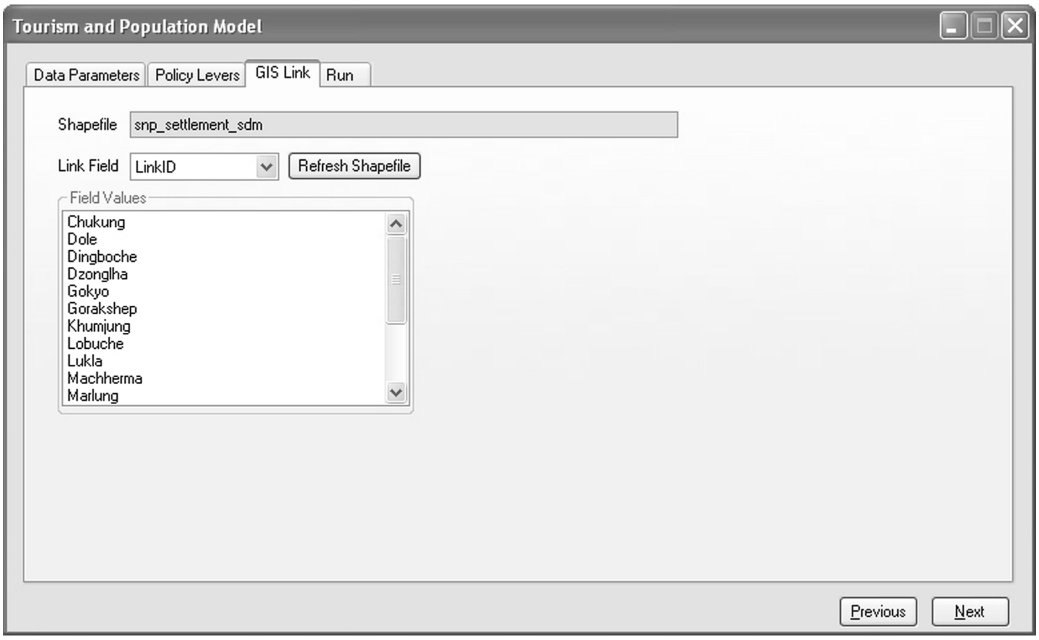


- Click **Next** button to move on to the GIS Link tab.

GIS Link

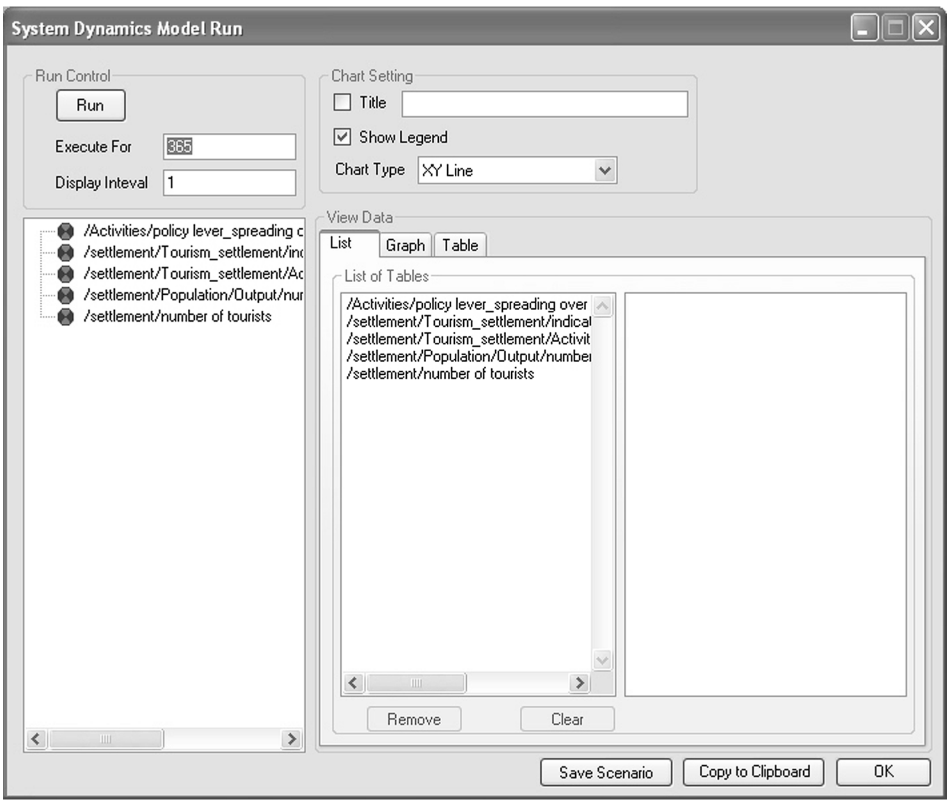
The model output will be linked to the **snp_settlement_tourism** GIS layer in **Spatial Analysis** module based on its **LinkID** field. Notice that this layer is shown in **Shapefile** textbox and **LinkID** field selected under **Link Field** drop-down.

- Click **Next** button to go to **Run** tab.

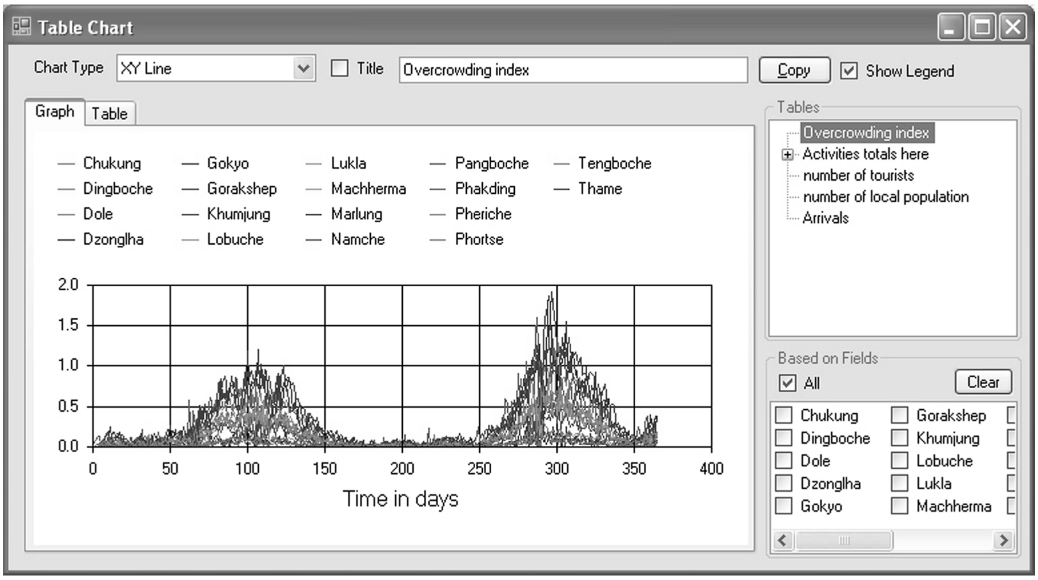


Run

- Click **Run Model** button under **Run** tab to launch the **System Dynamics Model Run** dialog.



- Accept the default settings in the **System Dynamics Model Run** dialog and click **Run** button to start running the model. The DST software will then run the model using **Simile Scripting** of **Simile** software.
- Once the model-run is complete, a **Table Chart** dialog is opened that allows viewing the outputs in the form of a graph or table.



Notice that the names of the output variables of the model are listed in **Tables** listbox with the first output variable in the list (i.e., overcrowding index) selected and its chart shown under the **Graph** tab.

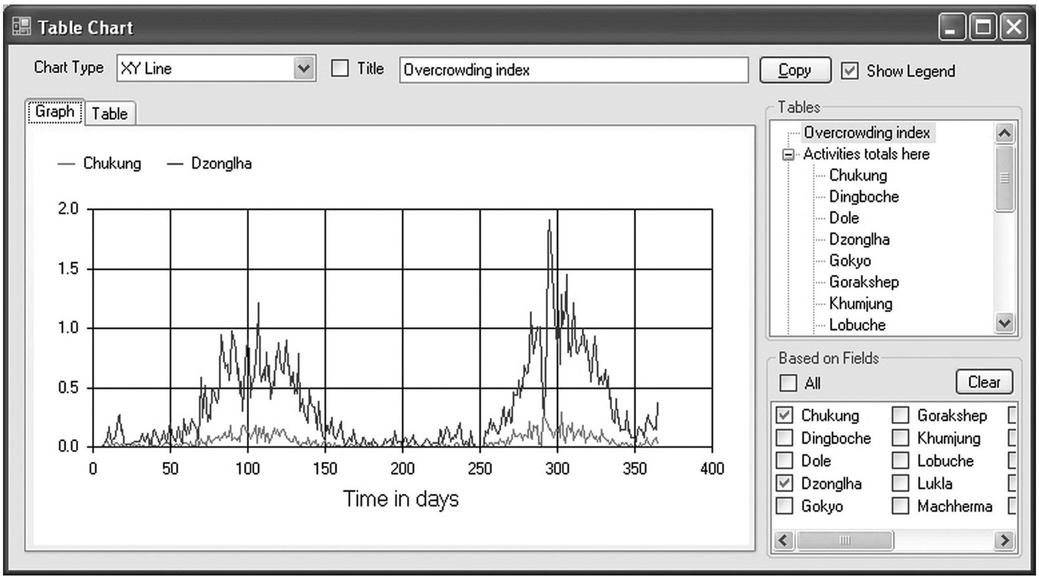
- If necessary, type the appropriate title for the chart in this textbox and set the **Title** checkbox on to add this title to the chart.
- Set the **Show Legend** checkbox on or off to show or hide the legend in the chart.
- Switch to **Table** tab if you want to view the output values in tabular form.
- Click **Copy** button to copy the current chart and table to the clipboard so that you can use it in other applications. For example, in Microsoft Excel, use Paste special feature to paste the graph as a Picture or Bitmap and use normal pasting to paste the table.

Different output variables may have different levels of hierarchies in their output tables depending on the way they are defined in the model. The **Table Chart** dialog allows users to view these different hierarchical outputs in both graphical and tabular forms. For example, in the case of **Overcrowding index** variable, the output table will have only one hierarchy as shown below:

Overcrowding index				
Time	Chukung	Dingboche	Dole	…
1	0	0	0	…
2	0	0	0	…
3	0	0	0	…
4	0	0	0	…
5	0	0.0034	0.0328	…
…	…	…	…	…

By default, the chart for overcrowding index is shown for all the 18 settlements of SNPBZ together. The **Table Chart** dialog allows viewing the graph and table for one or more selected settlements.

- At the bottom-right section of the **Table Chart** dialog, set the checkboxes of the settlements of your interest on. Notice that the graph will be updated for the selected settlements.

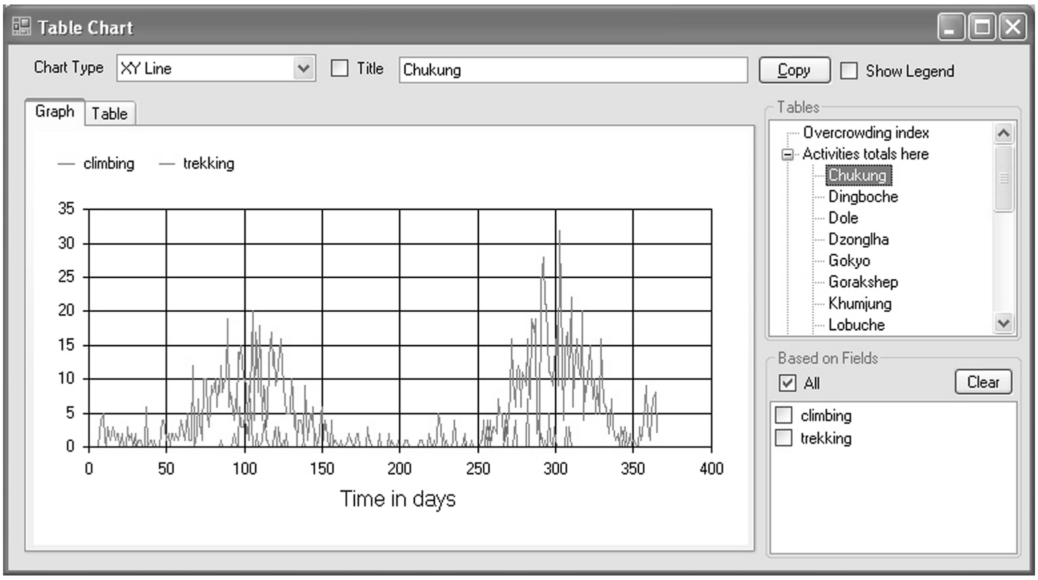


- Switch to **Table** tab if you want to view the corresponding tabular output.
- If you want to view the graphs for all the settlements, click **Clear** button and set **All** checkbox on.

However, in the case of **Activities totals here** output variable, there will be two levels of hierarchy based on settlement and activity as shown in the table below:

Activities total here								
Time	Chukung		Dingboche		Dole		…	
	climbing	trekking	climbing	trekking	climbing	trekking	climbing	trekking
1	0	0	0	0	0	0	…	…
2	0	0	0	0	0	0	…	…
3	0	0	0	0	0	0	…	…
4	0	0	0	0	0	0	…	…
5	0	0	0	2	0	4	…	…
…	…	…	…	…	…	…	…	…

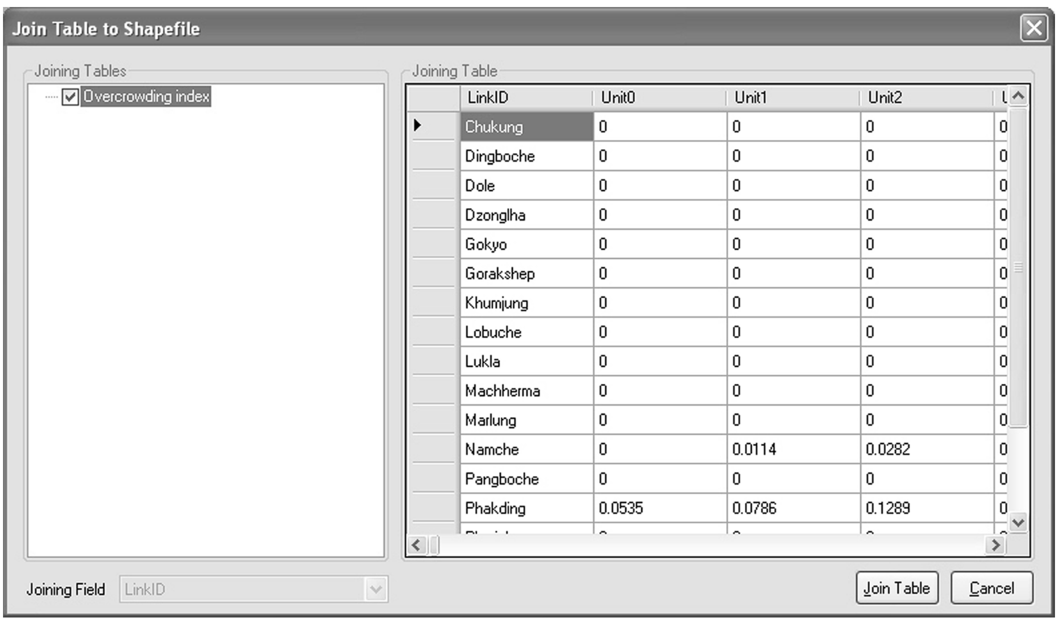
- Expand the tree for **Activities totals here** variable in the **Tables** listbox.
- Select a settlement of your interest to view the chart or table output for that settlement.



- Further, you can filter the outputs based on climbing or trekking activity by setting the corresponding checkbox at the bottom-right section of the **Table Chart** dialog.

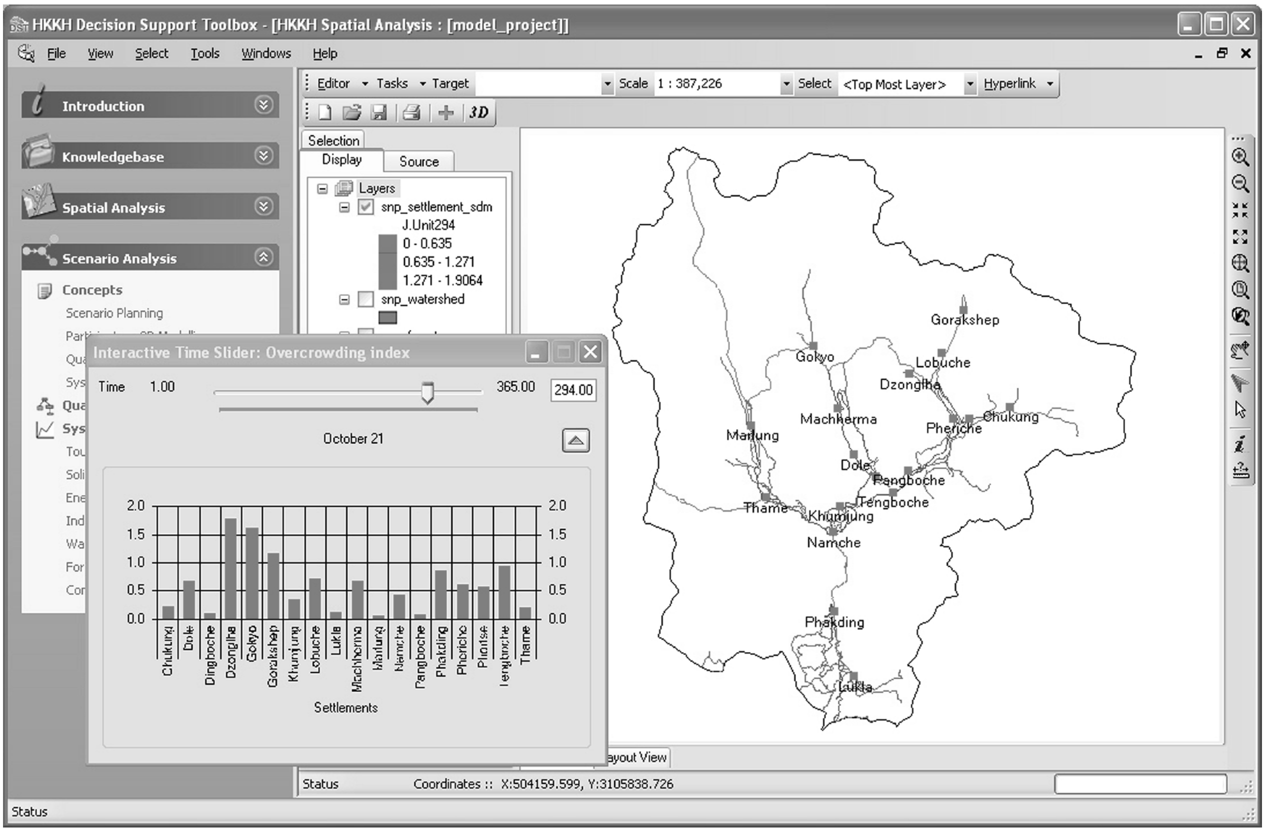
Joining the output variable to spatial layer

- Double click the Overcrowding index under the **Tables** listbox. This will open a **Join Table to Shapefile** dialog.



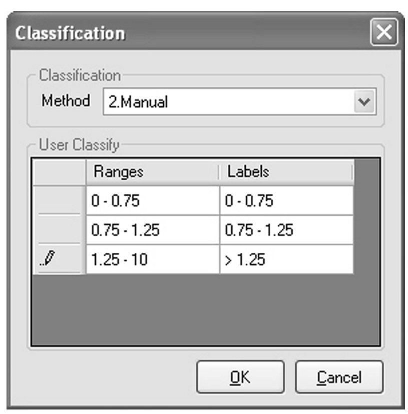
- Click **Join Table** button. This will join the daily temporal output for overcrowding index variable to snp_settlement_sdm layer present in **Spatial Analysis** module based on LinkID field, which contains names of 18 settlements in SNPBZ. The **Join Table to Shapefile** will vanish once the spatial joining is complete.
- If necessary, switch to **Spatial Analysis** module by selecting the appropriate link from **Windows** menu.
- Open the attribute table of **snp_settlement_tourism** layer to view the model outputs or the overcrowding indices joined to this layer. Close this attribute table after viewing is complete.

- Right-click the snp_settlement_sdm and click **Show Interactive Time Slider**. This will launch **Interactive Time Slider** dialog.
- Drag the slider in the **Interactive Time Slider** to view the overall overcrowding scenario in the 18 settlements for any given day. Notice that the day and the month for any given day are shown below the slider. The number shown in the textbox at the right section of the **Interactive Time Slider** denotes the day of the year.
- Click icon in the **Interactive Time Slider** to expand it to show a bar chart. Now when you drag the slider, a bar chart showing overcrowding index for settlements will be shown along with the dynamic map.

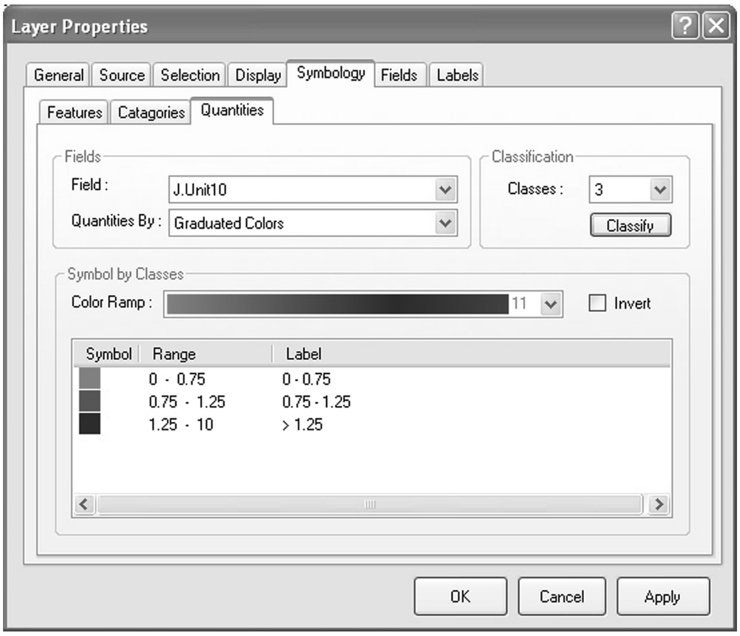


By default, the system creates a legend based on the value range for the whole year's overcrowding indices for all the 18 settlements by dividing this range into three equal class intervals. However, the users can choose their own classes and set the corresponding symbologies to define the legend for the snp_settlement_sdm layer (refer to **Symbolising features by quantities** sub section earlier for your reference).

- Note down the minimum and maximum value range of the whole output table.
- In the ToC, right-click the snp_settlement_sdm layer and click **Properties**.
- Click **Symbology** tab and switch to **Quantities** sub-tab.
- Under the **Field** drop-down select any joined attribute field which starts with the letter **J** (e.g., J.10).
- Click **Color Ramp** drop-down and choose any color ramp of your choice. Also, choose number of classes of your choice under **Classes** drop-down.



- Click **Classify** button and select Manual under **Method** drop-down in the **Classification** dialog.
- Set the upper bound value for each class under **Ranges** of **User Classify** section. For the last class, the system allows entering the number bigger than the maximum or upper bound value of the chosen attribute so that the user-defined classes can be applicable to all the joined fields. Use the maximum value of the whole output table that you noted down earlier for the reference.
- Click **OK** to close the **Classification** dialog.



- **Click Apply to** view the symbology applied to the feature layer on the map window.
- Click **OK** to close the **Layer Properties** dialog.
- If you want, click the symbology of an individual class of the snp_settlement_sdm layer in ToC and set the colour of your choice for that class.

As a quick guideline, the main outputs of the Tourism and Population Model are given in the table below:

Output Variable Name	Description and Unit
Overcrowding index	This index is calculated as the ratio of number of tourists spending overnight at a settlement and bed capacities of that settlement and provides a measure of shortage/abundance of accommodation in the settlement for a given day.
Activities total here	Daily number of trekkers and climbers on 18 given settlements in SNPBZ [Number]
Number of tourists	Daily number of tourists on 18 given settlements in SNPBZ [Number]
Number of local population	Daily number of local population including porters and guides [Number]
Arrivals	Daily trekkers and climbers entering SNPBZ [Number]

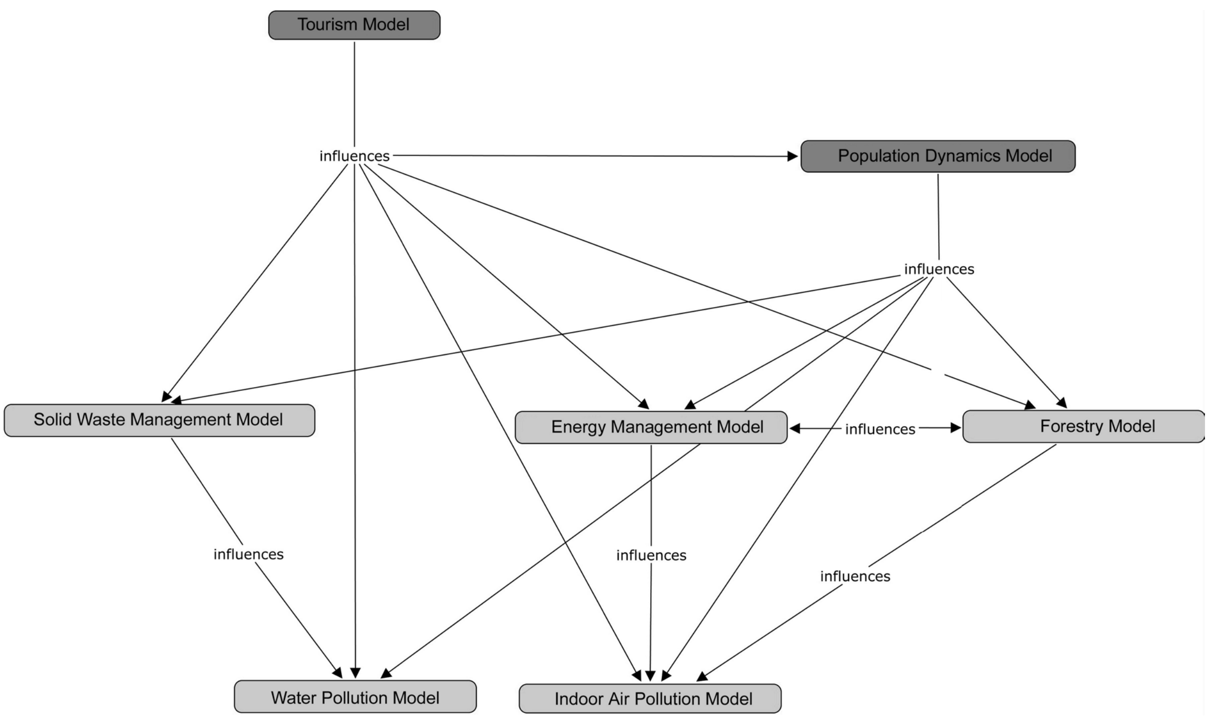
Chapter 14

Running Solid Waste, Energy, Indoor Air Pollution, Water Pollution and Forestry Models

As described in previous chapters, the HKKH Partnership project has developed Tourism and Population Dynamics models that run on daily time step and other five models that run on monthly time step as given below:

- Solid Waste Management model
- Energy Management model
- Indoor Air Pollution model
- Water Pollution model
- Forestry model

The project has identified tourist and local population as the key drivers for all the remaining five models and has established connections with various models as shown in the conceptual diagram below:



The project has developed a composite model (referred to as *Monthly Composite Model* hereafter) containing all the five monthly models as sub-models within that big monthly composite model. The relationships between various models are clearly defined in this model. This model allows users to set policy levers for multiple connected models and run all the five models as one big integrated model. This model, in the form of composite.sml file, is stored in the user's computer at:

..\Scenario Analysis\System Dynamic Models\SimileModels\CompositeModels

The files containing input data related to individual models are stored in relevant sub-folders at:

..\Scenario Analysis\System Dynamic Models\SimileModels\CompositeModels

For example, all the input files related to *Solid Waste* model are stored in **Solid data** folder in the above location.

The *Monthly Composite Model* that contains five inter-connected individual models takes monthly tourist and local populations as two major inputs. The DST provides the following three options regarding the use of these data as inputs to this composite model:

- **Use default population data:** This option will use monthly population data that was obtained by running the Tourism and Population model without any tourism policy and converting the daily population to the monthly population. The **tourist_local_pop_monthly.csv** file that stores these default monthly population data can be found at **..\Scenario Analysis\System Dynamic Models\SimileModels\CompositeModels\Tourism data** folder.

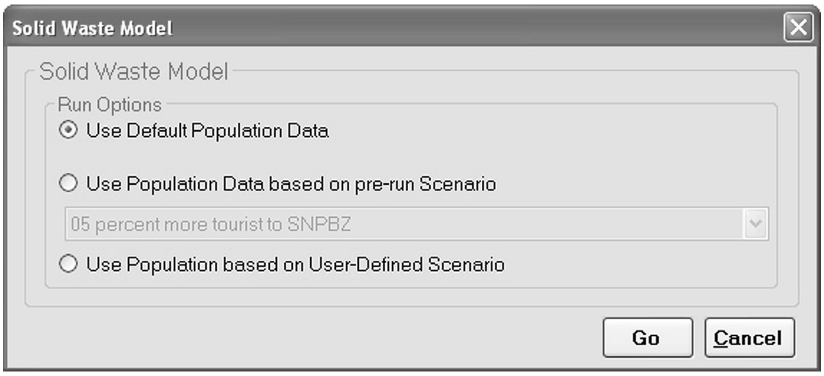
- **Use population data based on pre-run scenario:** Using different values for **% Tourism flow variation** policy lever in Tourism and Population model, a number of scenarios (e.g., 5 % more tourists going to SNPBZ) were generated. The files storing monthly tourist and local population based on those scenarios can be found at **..\Scenario Analysis\System Dynamic Models\SimileModels\CompositeModels\Tourism Scenario** folder. This option allows users to choose population data based on these pre-run scenarios.

- **Use population data based on user-defined scenario:** This option allows users to run the Tourism and Population model by setting their own tourism policies such that DST converts the daily tourist and local population outputs into monthly populations on the fly and use them as inputs to the *Monthly Composite Model*.

The DST provides customised interfaces for each of the models such that users can set policy levers for any given model, run the model and obtain the outputs for that model. In cases where the model is dependent on other models, the DST allows users to set policy levers for those dependent models too. Although it appears to the users as if they are running an individual model, in reality, the DST runs the *Monthly Composite Model* and provides the outputs related to that model only. The following sections provide step-by-step guides to run each of the five monthly models. Please refer to earlier chapters on individual models for detailed information on input variables, policy lever variables and output variables of the models.

14.1 Running Solid Waste Model

- Click **Scenario Analysis** menu.
- Click **Solid Waste** sub-sub-menu under **System Dynamic Models** vertical sub-menu. This will launch a dialog that provides three options regarding the use of monthly tourist and local population as inputs as described earlier.



- Choose **Use default population data** option or **Use Population data based on pre-run scenario** option and select from a drop-down a pre-run monthly tourism and local population data and click **Go.**
- Alternatively, choose **Use population based on user-defined scenario** option and click **Go**. This will launch the **Tourism and Population Model** dialog that allows setting your own tourism policy levers and running the *Tourism and Population* model. The DST software will run this model and convert the daily population outputs to monthly populations to feed them as inputs to *Monthly Composite Model*.

Data Parameters

The **Data Parameters** tab under **Solid Waste Model** dialog lists all the input variables required to run the *Monthly Composite Model*.

- Click **View/Edit** next to the variable of your interest to see the corresponding data related to that variable.

Categorised Data Parameters

- The **Catogorised Data Parameters** tab under **Solid Waste Model** dialog lists all the input variables related to *Solid Waste* model.

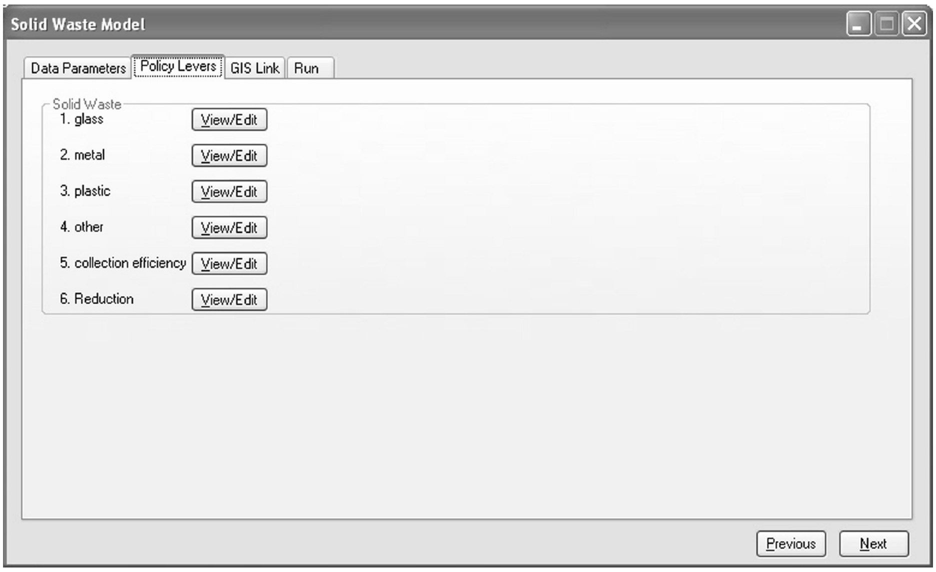
- Click **View/Edit** next to the variable of your interest to see the corresponding data related to that variable.

Policy Levers

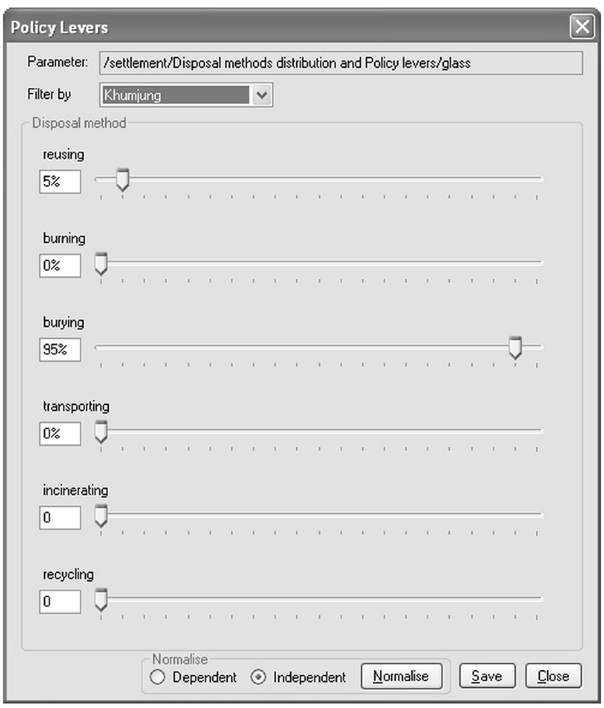
There are three different sets of policy levers considered in the *Solid Waste* model:

Policy Variable	Description	Value range
Disposal methods distribution	This policy allows users to set policy regarding how they want to manage wastes by assigning each waste type (i.e., glass, metal, plastic and other) to 6 different disposal methods (i.e., reusing, burning, burying, transporting, incinerating, and recycling) for any given settlement.	0 to 1
Collection efficiency	This policy allows changing the collection efficiency in terms of percentage for each waste type for any given settlement.	0 to 1
Reduction of waste production	This policy is related to reduction of each waste type in percentage for any given settlement in SNPBZ.	0 to 1

Disposal methods distribution



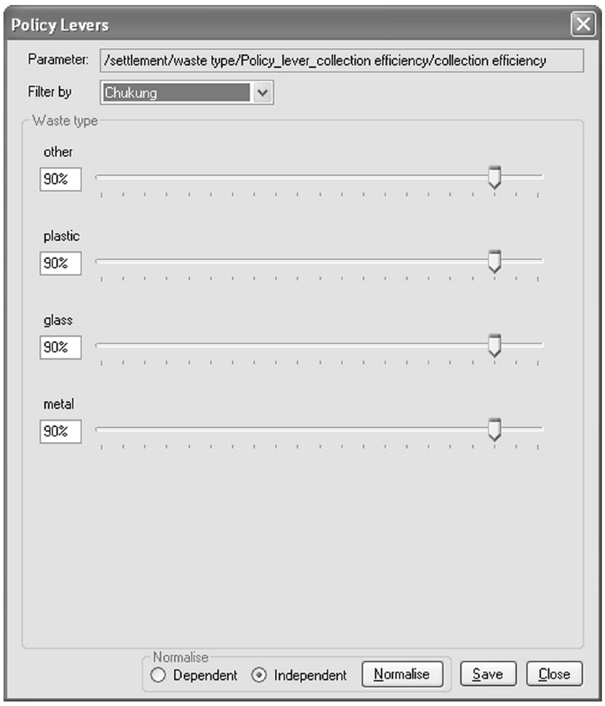
- If necessary, click **Next** to go to **Policy Levers** tab in **Solid Waste Model** dialog.
- Click **View/Edit** button next to **glass** to set the disposal method distribution for glass**.** This will open a dialog that allows assigning different disposal methods in terms of percentage for managing the waste type glass for selected settlement.
- Select a settlement for which the disposal method policy is to be applied from **Filter by drop-down**. Notice that the default values for different disposal methods (based on data collected by the project) are displayed.
- Change the existing disposal policy by assigning different weights to different disposal methods by dragging the corresponding sliders.



- Click **Normalise** button to normalise the weights so that sum of all the weights become 100%.
- Alternatively, select **Dependent** option under **Normalise** option-group and change the weights for a disposal method of your choice. Notice that the sliders for other disposal methods will be automatically adjusted to make the sum of all the weights 100%.
- Click **Save** to set your disposal policy for glass waste type.
- Repeat these steps for other settlements and finally click **Close** to close the **Policy Levers** dialog.
- Similarly, set your policy of disposal methods for other three waste types: metal, plastic, and other.

Note: Users need to be careful while assigning the weights. For example, assigning weight other than zero for metal will not be meaningful.

Collection efficiency



- Click **View/Edit** next to **collection efficiency** under **Policy Levers** tab in **Solid Waste Model** dialog.
- Select a settlement for which you want to apply this policy from **Filter by** drop-down.
- The default efficiency value for each waste type is shown in the dialog. Change the collection efficiency for each waste type for the selected settlement.
- Unlike in the case of disposal methods, these weights are applied independently for each waste type and therefore, do not click **Normalise** button.
- Click **Save** to apply the collection efficiency policy for the selected settlement.
- Repeat these steps for other settlements and finally click **Close** to close the **Policy Levers** dialog.

Reduction of waste production

It allows users to set policy regarding reduction of each waste type in percentage in any given settlement in SNPBZ.

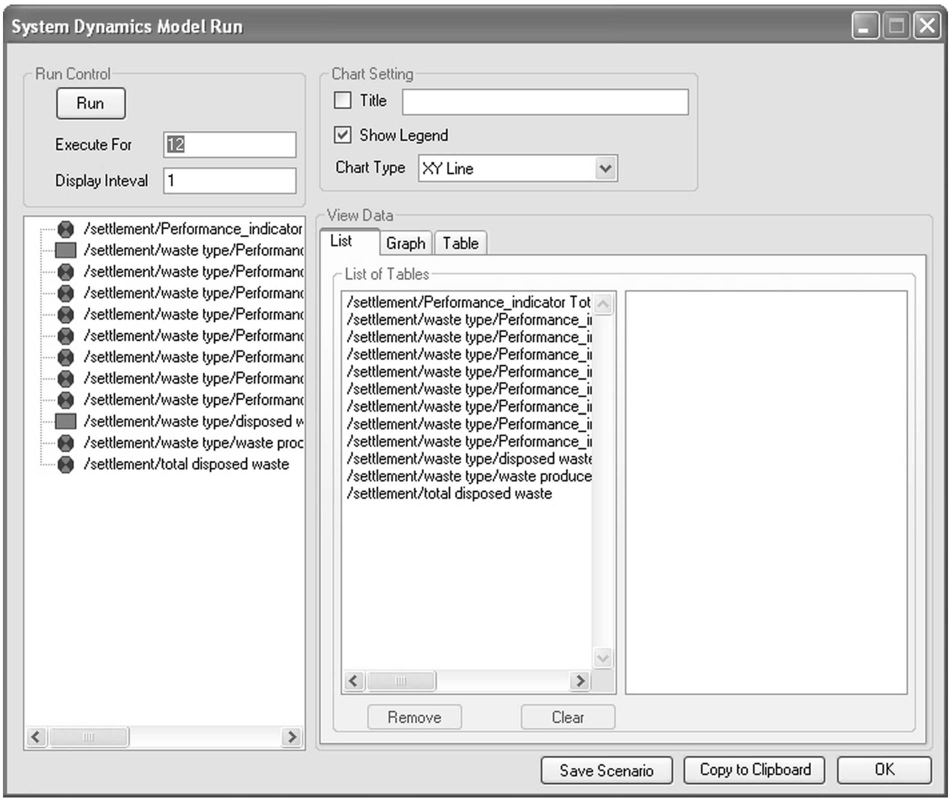
- Click **View/Edit** next to **Reduction** under **Policy Levers** tab in **Solid Waste Model** dialog.
- Use similar steps as described in collection efficiency policy lever to apply this policy to different settlements.
- Finally, click **Next** to go to **GIS Link** tab.

GIS Link

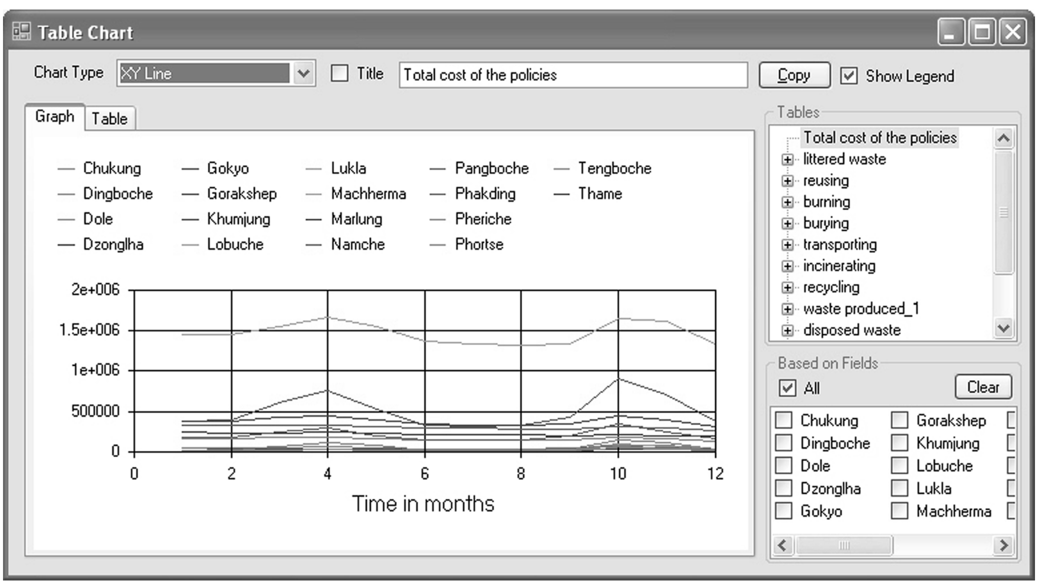
Accept the default values and click **Next** button to go to **Run** tab.

Run

Click **Run Model** button under **Run** tab to launch the **System Dynamics Model Run** dialog.

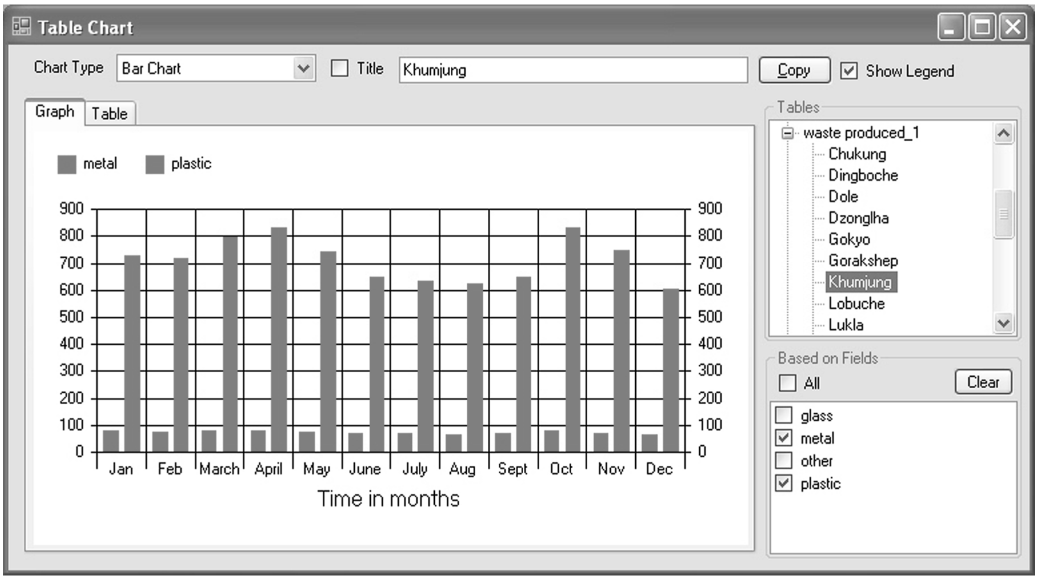


- Accept the default settings in the **System Dynamics Model Run** dialog and click **Run** button to start running the model.
- Once the model-run is complete, a **Table Chart** dialog is opened that allows viewing the outputs in the form of chart and table.



Notice that the first output variable in the **Tables** listbox is selected by default and the corresponding chart is shown under **Graph** tab.

- View the graphical and tabular outputs for output variables listed in **Tables** listbox in different ways as explained in *Running Tourism and Population Model* chapter.



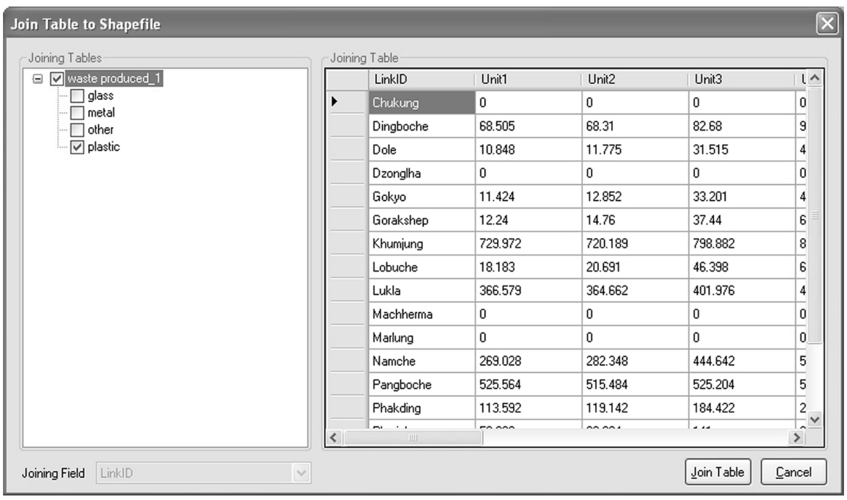
The following table provides a list of output variables for *Solid Waste* model.

Output Variable Name	Output Type	Description and Unit
waste_produced_1	Performance indicator	actual production of waste before further processing [Kg]
reusing	Performance indicator	the total waste reused [Kg]
burying	Performance indicator	the total waste buried [Kg]
burning	Performance indicator	the total waste burned [Kg]
transporting	Performance indicator	the total waste transported outside [Kg]
recycling	Performance indicator	the total waste recycled [Kg]
Littered waste	Performance indicator	amount of waste in kilograms that is neither segregated nor disposed, but assumed to be littered on the ground in the park [Kg]
Total cost of the policies	Performance indicator	the total costs connected to the management levers of the model, including costs due to incineration, recycling processes, transporting activity, reduction of waste production and waste collection [Nepalese rupees(NRS)]

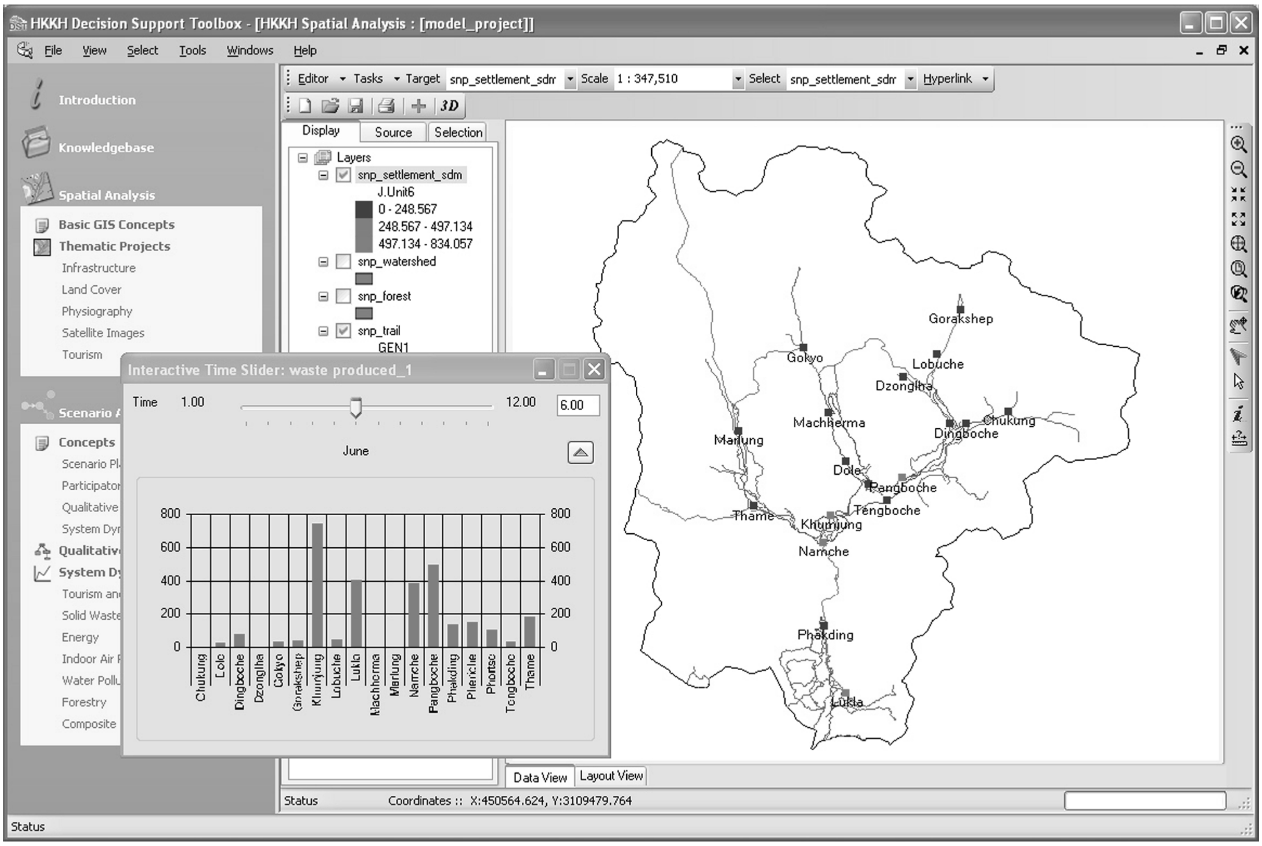
Waste produced_0	Intermediate	amount in Kilograms of waste produced in each selected settlement together by local population and tourists, without considering the policy lever of reducing the amount of waste produced [Kg]
Disposed waste	Intermediate	total amount in Kilograms of disposed waste (i.e., the sum of buried, burned and incinerated waste) by waste type.
Total disposed waste	Intermediate	total amount in Kilograms of waste disposed without waste type distinction.

Joining the output variable to spatial layer

- Double click the output variable that you want to join to settlement layer in **Spatial Analysis** module. This will open a **Join Table to Shapefile** dialog.



- If the output variable has hierarchical outputs select the appropriate variable in the next hierarchy. For example, in the above figure, plastic waste type under waste_produced_1 variable has been chosen for spatial linkage.
- Click **Join Table** button. This will join the daily temporal output for the selected variable to snp_settlement_sdm layer present in **Spatial Analysis** module based on LinkID field which contains names of 18 settlements in SNPBZ. The **Join Table to Shapefile** will vanish once the spatial joining is complete.
- Switch to **Spatial Analysis** module by selecting appropriate link from **Windows** menu.
- Right-click the snp_settlement_sdm and click **Show Interactive Time Slider**. This will launch **Interactive Time Slider** dialog.
- Drag the slider in the **Interactive Time Slider** to view the overall overcrowding scenario in the 18 settlements for any given month. Click  to expand it to view the dynamic chart output.



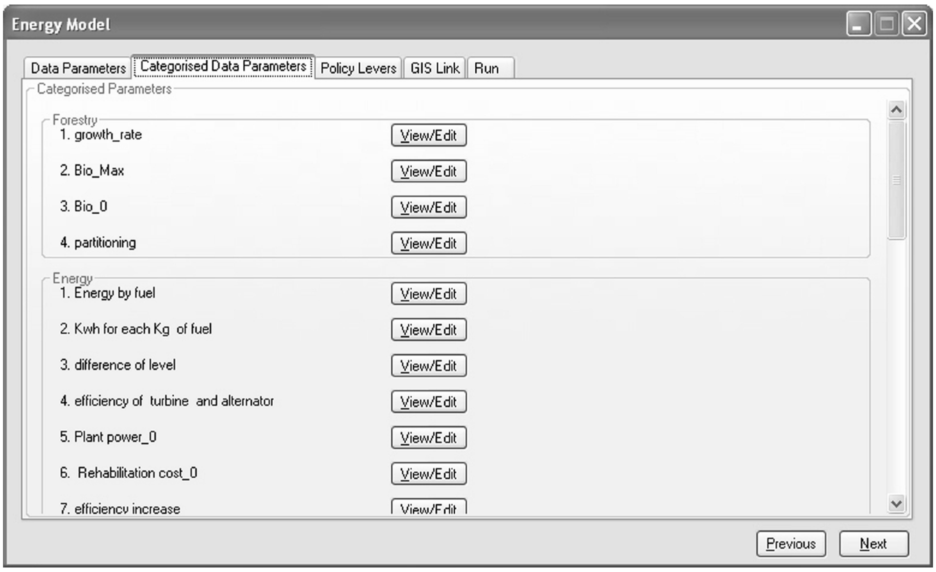
By default, the system creates a legend based on the value range for the whole year's overcrowding indices for all the 18 settlements by dividing this range into three equal class intervals. However, the users can choose their own classes and the corresponding symbologies to define the legend for the snp_settlement_sdm layer (see *Running Tourism and Population Model* chapter for reference).

14.2 Running Energy Model

- Click **Scenario Analysis** menu.
- Click **Energy** sub-sub-menu under **System Dynamics Models** vertical sub-menu.
- Follow the steps described in *Running Solid Waste Model* section to assign tourist and local population input data to the model and view the list of input variables and the corresponding data.

Policy Levers

The *Energy* and *Forestry* model are inter-connected such that the policies applied in one model will affect the outputs of another model and vice-versa. Therefore DST allows users to set policies for both *Forestry* and *Energy* models while running the Energy model.



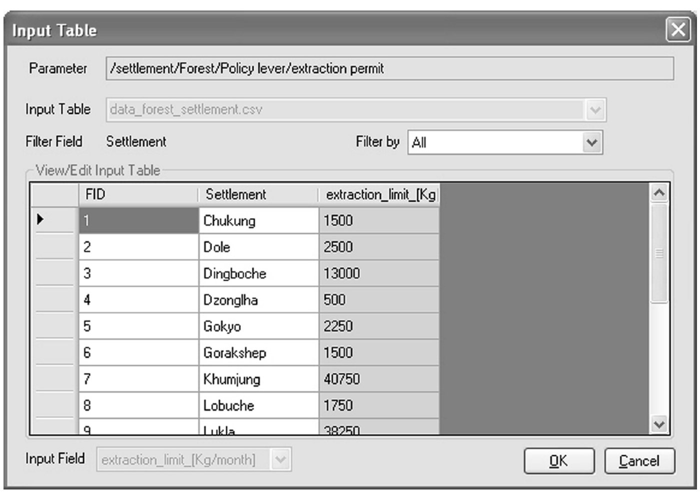
Forestry Policy Levers

There are three policy levers considered in the *Forestry* model as given in the table below:

Policy Variable	Description	Value range
Extraction permit	This policy refers to the amount of fuelwood in kilogram that inhabitants of each settlement of SNPBZ are allowed to extract from the selected forests.	0 to 1
Biomass reforestation	This policy refers to the amount of biomass in kilogram added to selected forests by inhabitants of each settlement by reforestation activity.	0 to 1
Patrolling	This policy lever is related to regulating the biomass extraction from the forest by introducing patrolling mechanism and takes value of 1 if this policy is introduced and 0 if otherwise.	0 or 1

Please refer to **Forestry Model** chapter earlier for detailed information on this model and its parameters.

- In order to set extraction permit policy, click **View/Edit** button next to **extraction permit** under **Policy Levers** tab of **Energy Model** dialog.



- Change the default extraction limit values for settlements of your interest in the **Input Table** dialog and click **OK** to save the changes.

- Similarly, click **View/Edit** button next to **patrolling** and type 1 for settlements where you want to introduce the patrolling policy and leave the default 0 value of remaining settlements using the similar interface as in the case of **extraction permit** policy.

- Click **View/Edit** button next to **Biomass reduction** and type the amount of reforestration in kilogram for settlements where you want to introduce this policy using the similar interface as in the case of **extraction permit** policy.

Energy Policy Levers

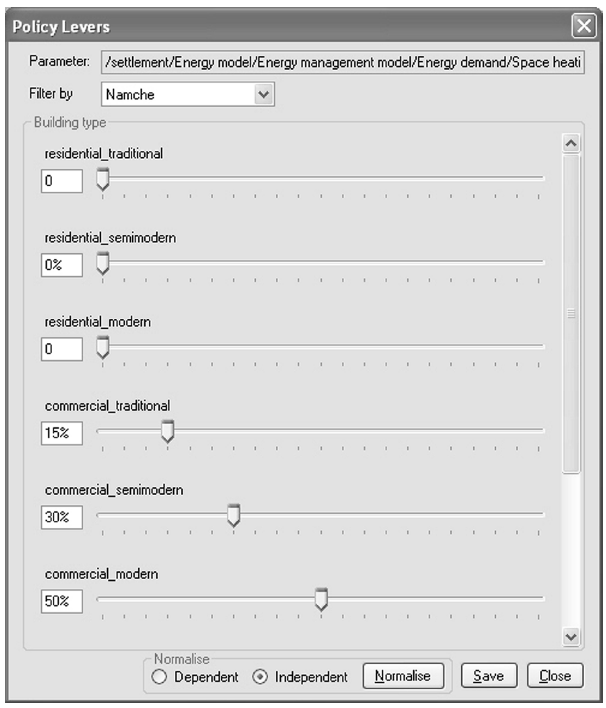
Please refer to *Energy Model* chapter for detailed information on this model and its parameters. The policy levers of the Energy model can be divided into two types: demand and supply.

Energy demand policy levers

Policy Variable	Description	Value range
U value reduction	This policy allows reduction of the thermal conductivity (i.e., U-value) by applying proper insulation in the buildings.	0 to 1
increase the use of energy saving lamps	This policy refers to the percentage of households substituting the traditional lamps with energy saving lamps.	0 to 1

U value reduction

- To set the policy lever for U value reduction, click **View/Edit** button for **U value reduction** under **Policy Levers** tab and select a settlement from **Filter by** drop-down.
- Using the sliders provided, set the U value reduction values for various building types.
- Do not click **Normalise** button since the values are applied independently to each of the nine building types considered in the model.
- Click **Save** to save the policy.
- Repeat the above steps to set the U value reduction policy for other settlements.
- Click **Close** to close the **Policy Levers** dialog.



Increase the use of energy saving lamps

- Click **View/Edit** button for **increase the use of energy saving lamps** and type percentage values for this policy for settlements using the similar interface as in the case of **extraction permit** policy as explained earlier.

Energy supply policy levers

There are eight policy levers under the energy supply category as given in the following table:

Policy Variable	Description	Value range
Sources reduction	% decrease of conventional energy sources, like firewood and fuels (kerosene, LPG diesel use)	0 to 1
New PV systems	% increase of overall area of photo-voltaic systems	0 to 1
New ST systems	% increase of overall area of solar thermal systems	0 to 1
New wind energy systems	% of newly installed wind energy systems	0 to 1
Percentage of use of the total hydropower energy	Percentage of use of the total hydropower energy used by each settlement	0 to 1
Percentage of use of the total new hydropower energy	Percentage of use of the total new hydropower energy used by each settlement	0 to 1
New hydropower plants	Power produced by newly installed hydropower plants in kilo watts.	0 to 10,000
Efficiency increase	Efficiency of turbine and alternator in existing hydropower plants	0 to 1

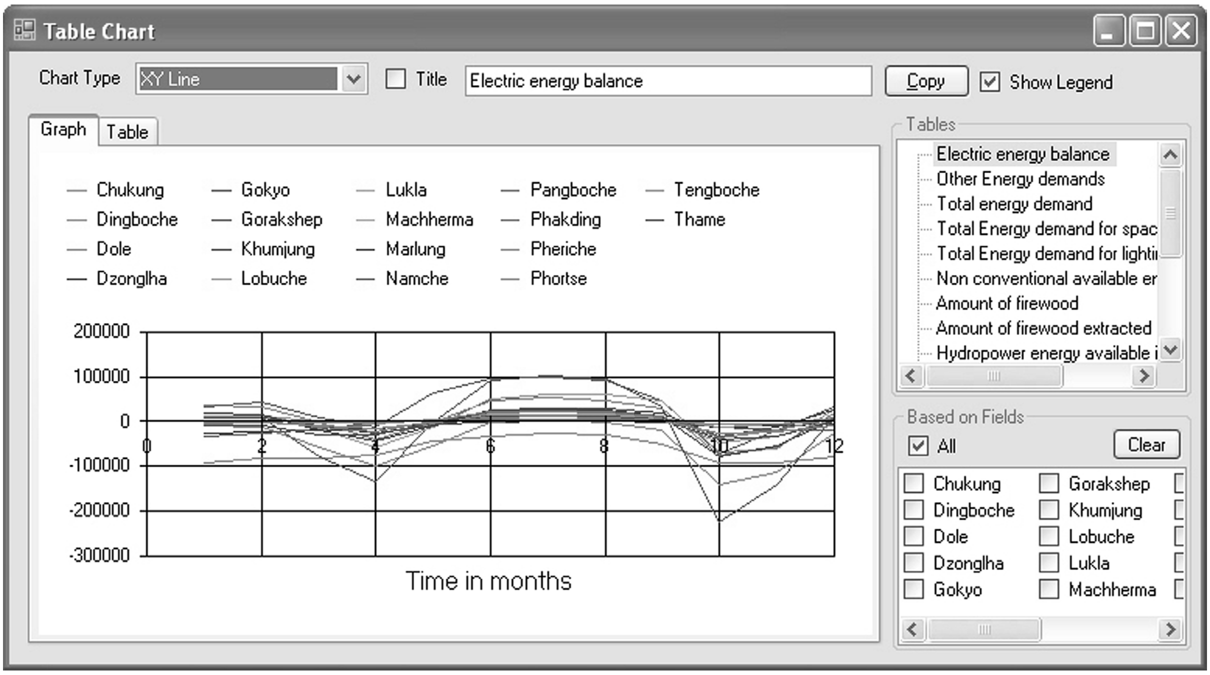
The users can set these policy levers using the similar interface as in the case of **extraction permit** policy as explained earlier.

GIS Link

- Once all the policy levers are set, click **Next** to go to **GIS Link** tab.
- Accept the default values and click **Next** button to go to **Run** tab.

Run

- Click **Run Model** button under **Run** tab to launch the **System Dynamics Model Run** dialog.
- Accept the default settings in the **System Dynamics Model Run** dialog and click **Run** button to start running the model.
- Once the model-run is complete, a **Table Chart** dialog is opened that allows viewing the outputs in the form of chart and table.



- View the graphical and tabular outputs using the **Table Chart** dialog and also visualise the outputs on map dynamically by joining the temporal output table to spatial layer as explained in *Running Solid Waste Model* section before.

The following table provides a list of output variables for Energy model.

Output Variable Name	Output Type	Description and Unit
Electric energy balance	Performance indicator	the total balance between energy supply and energy demand in each settlement [KWh]
Total costs	Performance indicator	the total cost of all the management levers as set by the user on park level [NRS]
Total settlement costs	Performance indicator	the total cost of policy levers applied on a settlement level [NRS]
Amount of firewood extracted	Intermediate	amount of effective firewood extracted in each settlement as regulated by extraction permits considering the *Forestry* model relevant policy lever [Kg]
Amount of firewood	Intermediate	amount of firewood that people in each settlement want to extract [Kg]
Total energy demand for space heating	Intermediate	amount of energy demanded for space heating for each building type in each settlement [KWh]
Total energy demand for lighting	Intermediate	amount of energy demanded for lighting per building type in each settlement [KWh]
Other energy demands	Intermediate	amount of energy demanded for other activities considered in the model, including cooking and kitchen utilities, entertainment, water pumping, hot water generation, per building type in each settlement [KWh]
Total energy demand	Intermediate	total sum of all energy demands for each settlement [KWh]

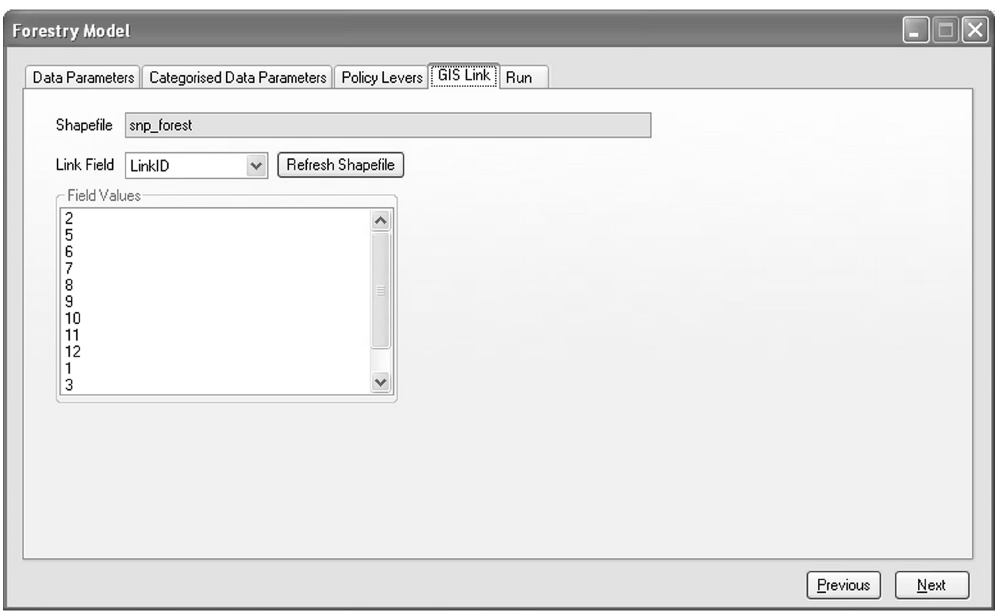
Conventional available energy	Intermediate	the total energy production from all conventional sources (firewood and fuels, including kerosene, LPG and dung) [KWh]
Non-conventional available energy	Intermediate	total energy produced by all non-conventional sources (photovoltaic, solar thermal, wind power energy systems) [KWh]
Energy produced by the hydropower plant	Intermediate	amount of energy produced by each hydropower station [KWh]
Hydropower energy available in the settlement	Intermediate	amount of hydropower energy used in each settlement [KWh]
Total hydropower energy supply	Intermediate	total energy produced (and available) by both already existing and new hydropower stations [KWh]
non connected balance	Intermediate	energy balance between energy supply and energy required by utilities that are not connected to electricity [KWh]:
connected balance	Intermediate	energy balance between energy supply and energy required by utilities that are connected with the electric energy [KWh]

14.3 Running Forestry Model

The steps involved in running the *Forestry* model and *Energy* model are identical to each other.

- Click **Scenario Analysis** menu.
- Click **Forestry** sub-sub-menu under **System Dynamic Models** vertical sub-menu.
- Follow the steps described in *Running Energy Model* section to run the *Forestry* model.

Notice that under **GIS Link** tab, snp_forest layer is populated in **Shapefile** textbox instead of snp_settlement_ sdm layer in earlier cases. This is because the *Forestry* model produces monthly outputs at forest level and therefore, the outputs need to be joined to forest layer if the users want to view the outputs dynamically on the map.

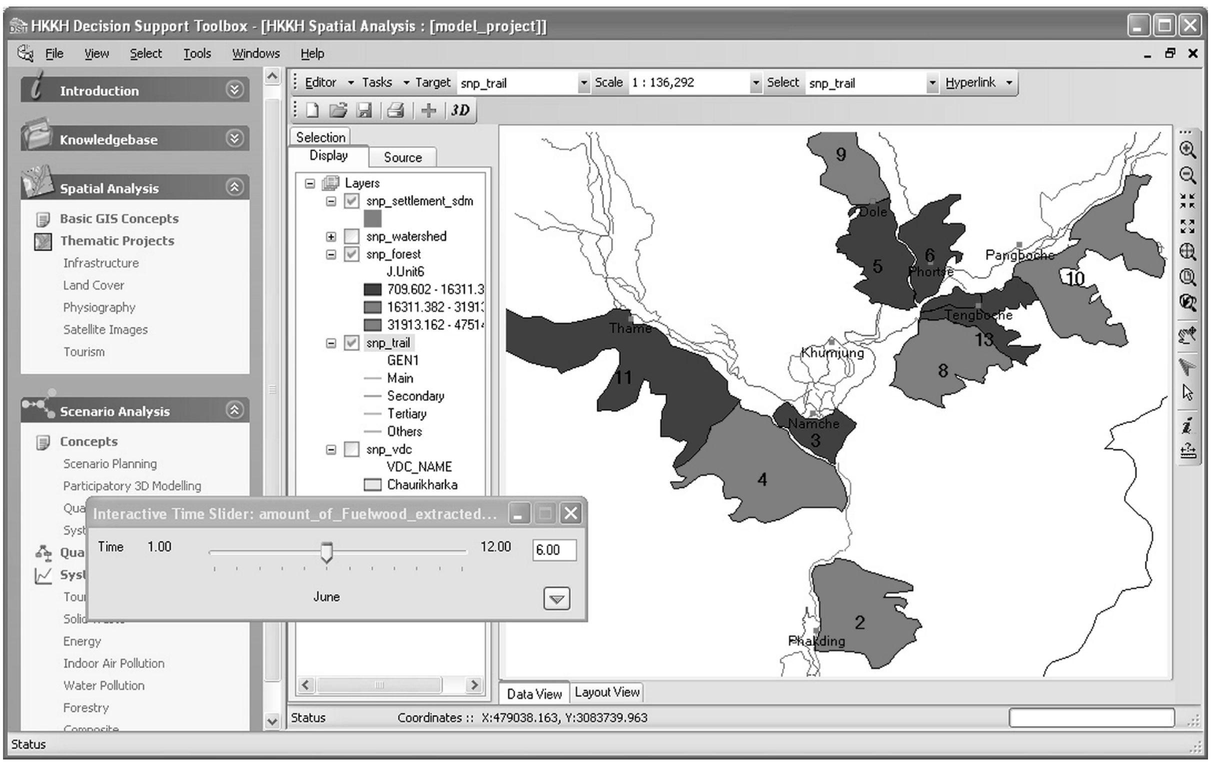


- View the graphical and tabular outputs using the **Table Chart** dialog and also visualise the outputs on map dynamically by joining the temporal output table to spatial layer as explained in *Running Solid Waste* model section before.

The *Forestry* model produces two outputs as given in the following table:

Output Variable Name	Output Type	Description and Unit
Biomass	Performance indicator	amount biomass in each forest area [Kg]
amount_of_Fuelwood_extracted_per_forest	Intermediate	amount of fuelwood extracted in each forest area. This variable also represents the aggregation by forest area of the variable Amount of firewood from the Energy model and disaggregated for settlement [Kg]

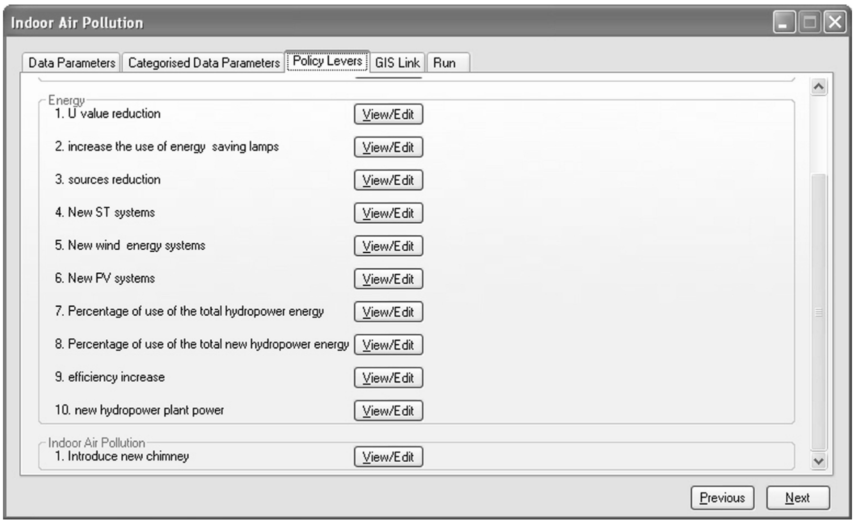
The *forestry* model considers 13 forests in SNPBZ and produces the above outputs for each of those 13 forests at monthly time step. The screenshot below shows the visualisation of the output for amount_of_Fuelwood_extracted_per_forest variable as an example:



14.4 Running Indoor Air Pollution Model

The *Indoor Air Pollution* model depends on the *Energy* and *Forestry* models and therefore its output will be affected by the policies for *Energy* and *Forestry* model.

The steps involved in running the *Indoor Air Pollution* is similar to running *Energy* or *Forestry* model except that users, in addition to setting policy levers for *Energy* and *Forestry* models, have to set an extra policy, i.e., **Introduce new chimney** related to *Indoor Air Pollution* model.



Introduce new chimney policy refers to introduction of new chimney to each of the nine building types at the SNPBZ level. This policy variable takes value of 1 if new chimney is introduced and 0 if otherwise.

The *Indoor Air Pollution* model produces three outputs as given in the table below:

Output Variable Name	Output Type	Description and Unit
State of health	Performance indicator	an index that shows the gravity of the disease in the settlement. It will assume an integer value comprised from 1 to 5 according to the gravity of the chronic obstructive pulmonary disease (COPD)
Total cost	Performance indicator	the total cost of the management lever as set by the user [NRS]
CO density in each house	Intermediate	the monthly average density of carbon-monoxide (CO) in each house per building type in each selected settlement [g/ m^3]

- Click **Scenario Analysis** menu.
- Click **Indoor Air Pollution** sub-sub-menu under **System Dynamic Models** vertical sub-menu.
- Follow the steps described in *Running Energy Model* section to set the policy levers and run the model.
- View the graphical and tabular outputs using the **Table Chart** dialog and also visualise the outputs on map dynamically by joining the temporal output table to spatial layer as explained in *Running Solid Waste* model section before.

Note: The *Indoor Air Pollution* model produces -9999 as output for certain building types for **State of health** and **CO density in each house** output variable. This is because those building types do not have data for Natural Ventilation input variable and its value has been set to zero by default.

14.5 Running Water Pollution Model

The *Water Pollution* model is dependent on the outputs of Solid Waste model. Therefore in order to run the *Water Pollution* model, the users need to set policies for both *Solid Waste* and *Water Pollution* models.

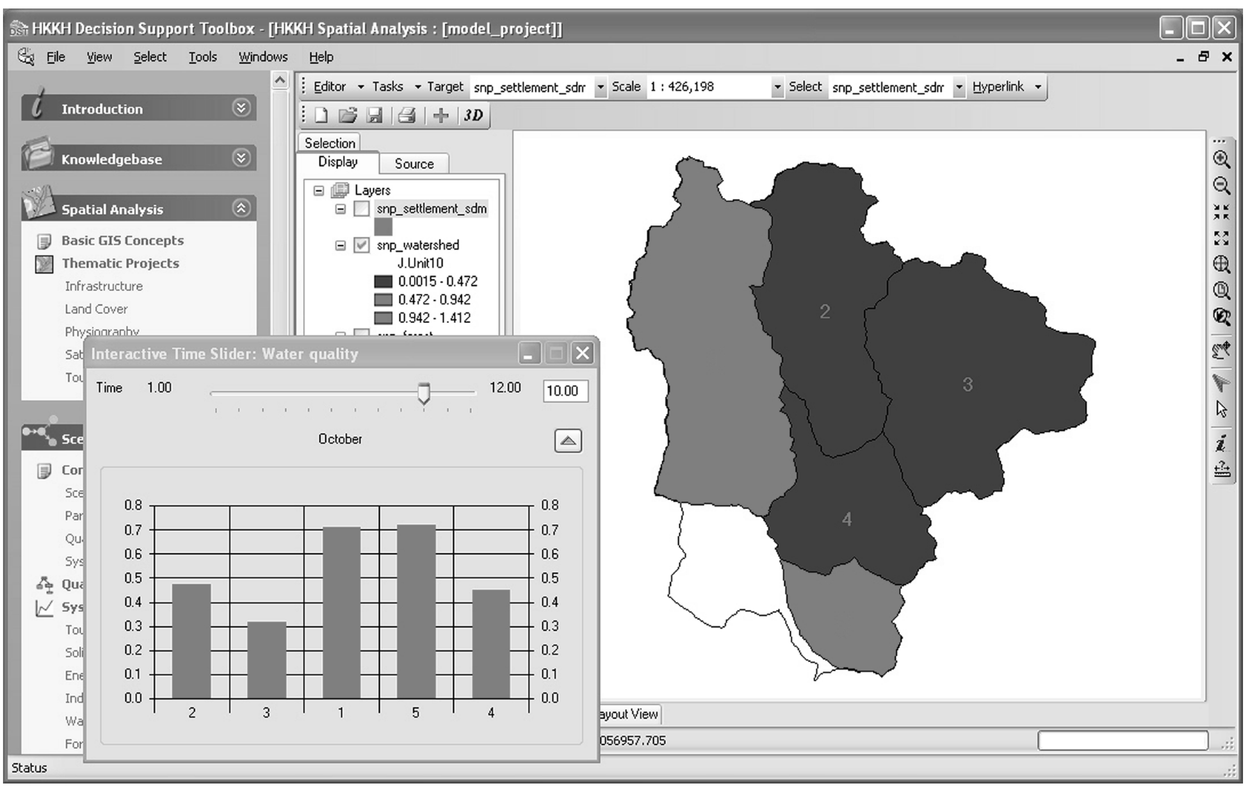
- Click **Scenario Analysis** menu.
- Click **Water Pollution** sub-sub-menu under **System Dynamic Models** vertical sub-menu.
- Follow the steps described in *Running Solid Waste Model* section to set the policies for *Water Pollution* model.

Water Pollution Policy Levers

The *Water Pollution* model has three policy levers as given in the table below:

Policy Variable	Description	Value range
Introduction of rows	Introduction of tree rows in terms of percentage on one side of the cultivated area to prevent the flow of nutrient from agriculture land to water body reducing potential load of nutrients in the water.	0 to 1
% of people for which septic tanks are to be built	This policy refers to percentage of people for whom septic tanks are to be built.	0 to 1
% decrease the of the number of cattle	This policy lever refers to the percentage of decrease of cattle.	0 to 1

- Refer to the steps described in *Running Energy Model* to set the above policy levers and run the model.
- View the graphical and tabular outputs using the **Table Chart** dialog and also visualise the outputs on map dynamically by joining the temporal output table to spatial layer as explained in earlier sections.



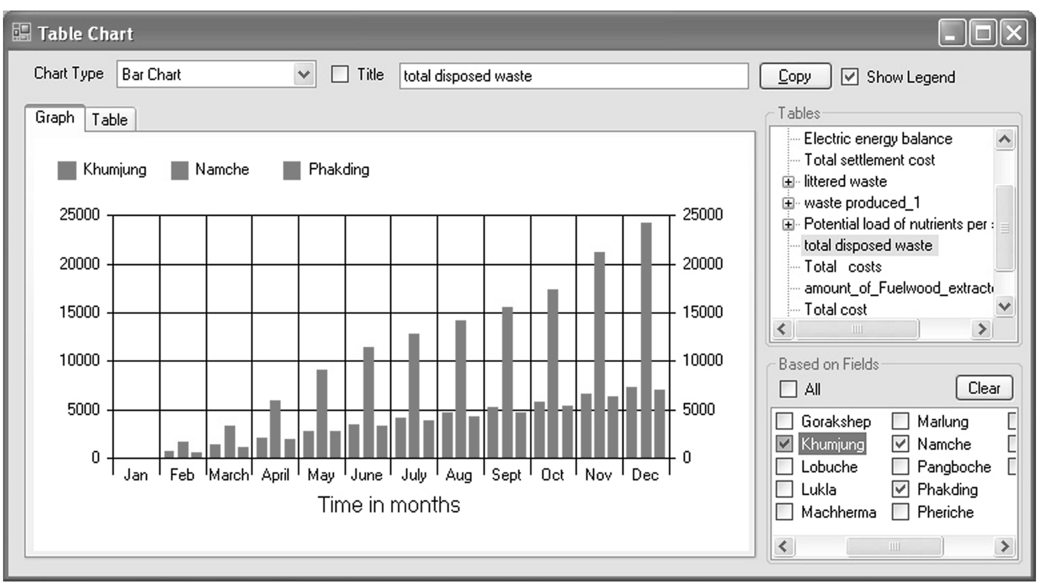
The Water Pollution model produces four outputs as given in the following table:

Output Variable Name	Output Type	Description and Unit
Potential load of nutrients per settlement	Performance indicator	provides the potential load of nutrients per settlement
Water quality	Performance indicator	index that shows the quality of the river according to the chemical parameter/s considered in the river (N-NO3, P-PO4, TN, TP, generic parameter). River conditions are good if the index is around 1, meaning that there are only natural loads of selected chemical parameter. The increased index value indicates the decreased water quality condition from its natural state.
Total costs	Performance indicator	the cost involved in implementing a management option is dependent on the value chosen for a management lever. [NRS]
Concentration of chemical nutrients in the river	Intermediate	provides a measure for concentration of nutrients in the river

14.6 Running Composite Model

As explained before, when a user runs any individual monthly model, the DST software provides GUIs relevant to that model and runs a *Monthly Composite Model* in the background and finally provides outputs specific to that model. In addition, the DST also lets users run the monthly composite by allowing them to set policy levers for all the individual models.

- Click **Scenario Analysis** menu.
- Click **Composite** sub-sub-menu under **System Dynamic Models** vertical sub-menu.
- Follow the steps similar to the ones described in *Running Solid Waste Model* section to set the policies for all the individual models.
- View the graphical and tabular outputs using the **Table Chart** dialog and also visualise the outputs on map dynamically by joining the temporal output table to spatial layer as explained in earlier sections.



Building partnerships for the HKKH region

The project "Institutional Consolidation for the Coordinated and the Integrated Monitoring of Natural Resources towards Sustainable Development and Environmental Conservation in the Hindu Kush-Karakoram-Himalaya Mountain Complex" (HKKH Partnership project) is a regional initiative aimed at consolidating institutional capacity for systemic planning and management of socio-ecosystems at the local, national and regional levels in the HKKH region. The project, supported by the Italian Cooperation, is implemented by International Union for Conservation of Nature (IUCN), CESVI, Ev-K2-CNR Committee and International Centre for Integrated Mountain Development (ICIMOD).

Web links:
http://www.hkkhpartnership.org
http://www.iucn.org
http://www.cesvi.org
http://www.evk2cnr.org
http://www.icimod.org