even a text message! In the Bohol model, 3 classes of messages were made:

1. FishermanComplaint – this message is actually a signal that a fisherman is complaining about him/her not being able to catch fish in a certain area. It is only sent on this occasion and is sent to a fisher folk group to which a fisherman belongs.
2. FisherfolkComplaint – this message contains the number of fishermen complaining in a particular group of fisher folk and is sent to the LGU every end of the month for deliberation.
3. Pressure – this message contains a type of occupation of an inhabitant is sent by an inhabitant to another inhabitant. It is sent when a particular inhabitant is earning well in his/her occupation and tries to tell other inhabitants s/he knows personally that his type of occupation earns well. This message is sent at the end of every month.

2) Simple Object – Weather in this case was considered as a simple object. The methods for weather are actually about generating the condition of weather for one day (or time-step), i.e. whether it's good or bad. A simple model of weather was made and is dependent on the months of a year. The first half of the year representing the dry season would have less chances of having a bad weather as compared to the later months of the year. The methods used for modeling weather were just assumed, but in accordance with the wet and dry seasons of the Philippines.

Sequence Diagram

The sequence diagram shows when each activity or task is performed, and which entity is performing the task in one time-step. In Cormas, this would be found in the control of the model. One time-step may differ from model to model. For the Bohol model, a base sequence diagram was created and for other scenarios, the sequence was modified to accommodate new tasks. Also, one time-step in the Bohol model is equivalent to one day.

The step-by-step tasks are listed as follows:

1) Weather is generated for the whole model.
2) The information about the weather is given to the inhabitants by the model.
3) The inhabitants are then activated to perform their tasks according to their occupation. Also, the poisons, if there are any, are activated. Since each operation or task is performed one at a time in Cormas, the agents are activated one by one in random order.
4) Pond workers who have harvested their fishponds earlier are selected. Poison agents are created based on the number of pond workers who have harvested. The selected pond workers who have wealth above zero send a "Pressure" message to each of their acquaintances or the other inhabitants

they know. After which, they read their messages ("Pressure") and then decide whether or not to change jobs (the activity diagram for change job procedure is shown in Fig. 4.25).

5) If it's the end of the month (a counter for the model, "modelTimer," is set-up to count the days for the month) several activities are performed. Jobs outside of Loon are created or made available to the inhabitants. The fishermen and farmers of the model are selected. Again if their wealth is above zero, they each send a "Pressure" message to each of their acquaintances. They then read their messages. They are now made to decide whether they want to change their jobs or not. The fisher folk of each barangay will send its complaint to the LGU (via FisherfolkComplaint). The timer for the month is then reset to1. If it is not the end of the month, modelTimer adds 1 to itself.
6) If it is the end of the year (a counter for the model, "modelTimer2," is set-up to count the days for the year), the population of the inhabitants is increased and modelTimer 2 is reset to 1. If it's not the end of the year, modelTimer2 adds 1 to itself.
7) The cells of the environment are activated to perform their tasks.
8) All the "dead" poisons are removed from the model.
9) Finally, the charts for the probes of the model are then updated. This is the end of one time-step and all the previous steps are repeated for a number of times specified by the modeler/user.

Figure 4.26 summarizes the above-mentioned steps. For other scenarios, the LGU performs several tasks. For a scenario wherein the LGU just performs mangrove reforestation, the task is performed at the end of the month or at step 5) after the fisher folks have sent their complaints. For a scenario that "listens" to the fisher folks, the LGU declares which protected areas are now accessible to the inhabitants and then performs mangrove reforestation. Both are done at end of the month.

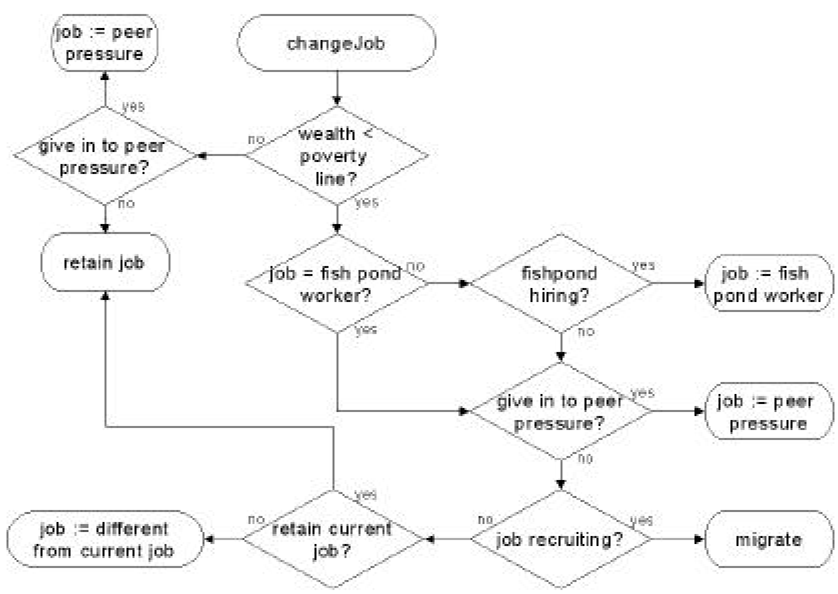

Figure 4.25 changeJob Activity Diagram

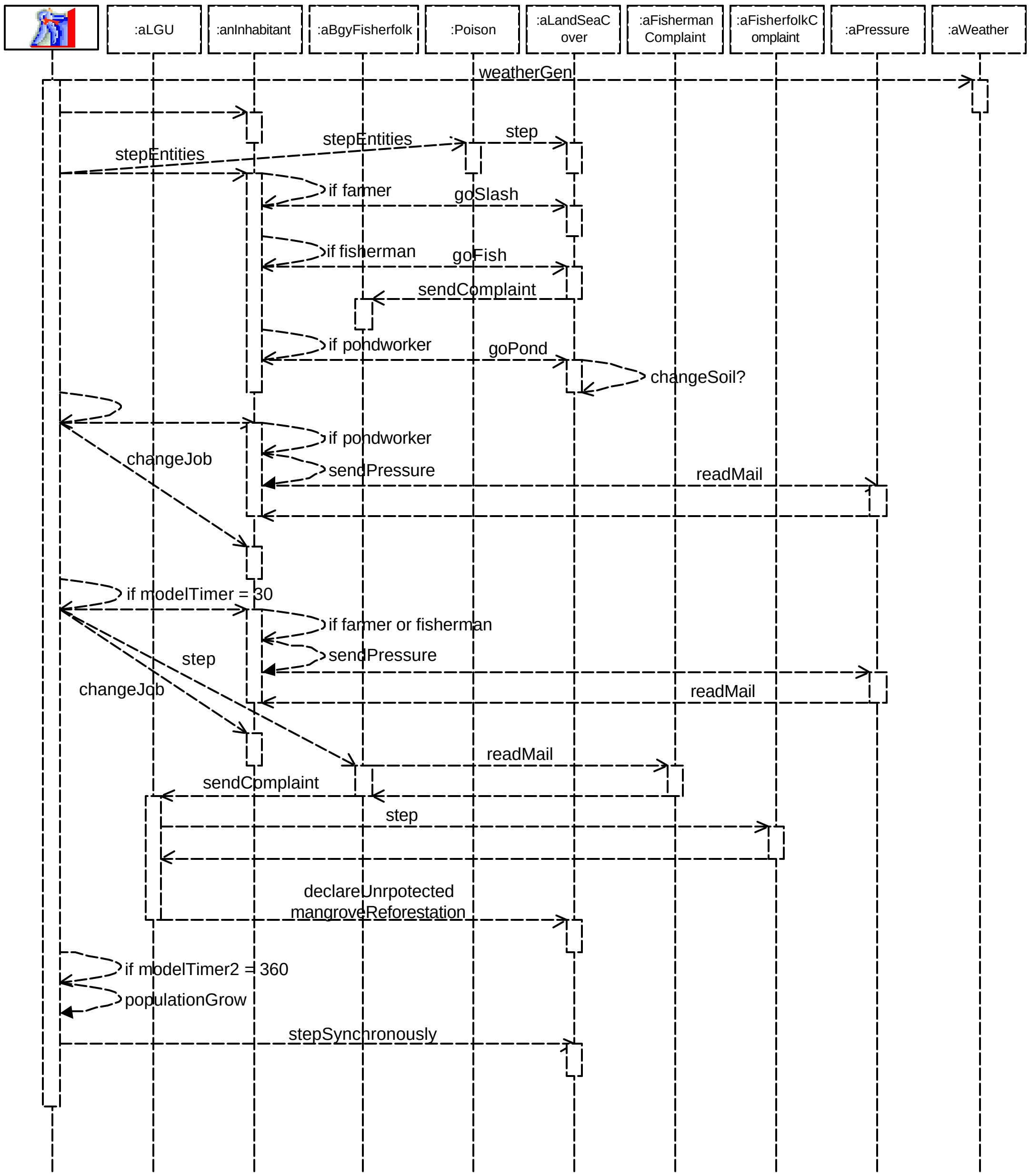

Figure 4.26 Bohol Model Sequence Diagram

4.2.5 Programming and Verification

The diagrams presented in this paper were developed in collaboration with the research team of Bohol. The diagrams were also presented in a training conducted in Thailand and was discussed by the participants and the trainers. Changes have been added to take into account the modifications made in the Bohol model.

Programming was done using the Cormas platform (examples of the source codes for the Bohol model is found in Appendix A of this research paper). The elementary spatial entity was created first and designed to accept the spatial data coming from the ArcView software. The environment was designed to have 5 layers of information, having a Moore neighborhood, and non-torroidal or closed boundaries. After inputting the spatial data, the programming of other entities was done. Assumptions have been made to make the program to function properly. A list of assumptions for the environment, social agents and passive objects is found in the appendices (Appendix B). Since the environment was large, having exactly 42,112 cells, testing the methods in the Bohol model would take a lot of time so a "synthetic" environment was set-up having a 20 x 20 grid size and was used for running and testing the model (see Figure 4.27). To see if the agents in the model are communicating properly a Communications' Observer Window (see Figure 4.28) was opened. As an example to verify the consistency of the model, with the probes of the model activated, 3 simulations were run for 1800 time steps each, and results of the probes, given as charts, were compared. The results and analysis for this exercise will be presented and analyzed in Chapter 5.

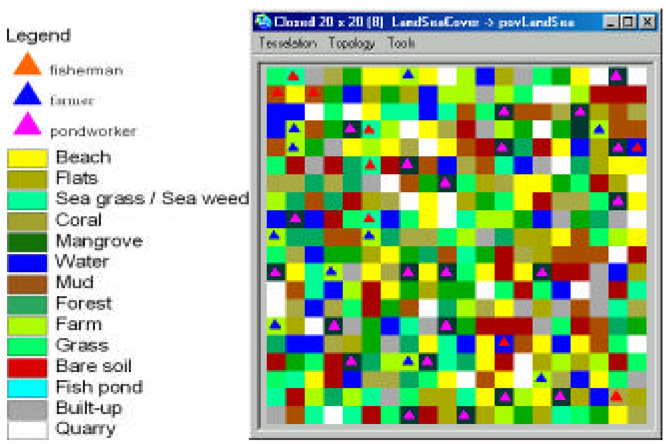

Figure 4.27 20 x 20 "Synthetic" Environment

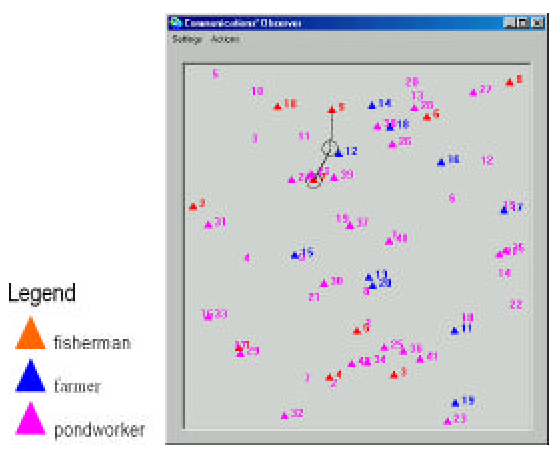

Figure 4.28 Communication's Observer Window

4.2.6 Simulation

For this research, 8 different scenarios were developed to take into account the role of the LGU in NRM and the attitude of the people towards rules or policies. Although this may not be what happens in reality, this, however, may show the potential of MAS modeling for testing policies to see how these policies may impact the environment and the stakeholders. The considerations for the LGU are: 1) they completely ignore the complaints of fishermen and ignore the state of mangrove areas; 2) they still ignore the complaints of the fishermen, but they perform mangrove reforestation (based on the interviews this happened recently); and 3) they listen to the complaints and do mangrove reforestation. The considerations for the inhabitants are: 1) that they completely follow the policies; 2) that they completely ignore the policies; and 3) that they have varying degree of chances of not following the policies. Combinations of the LGU's role and inhabitants' attitude would comprise the scenarios. A summary of the possible scenarios is given in Table 4.3. Note that these scenarios were developed based on the perceptions of the researcher and that there are other possible scenarios for NRM.

Table 4.3 Summary of Scenarios

Scenario	Role of LGU	Attitude of Inhabitants
1	Ignore the fishermen	Obey the policies
2	Ignore the fishermen	Break the law
3	Ignore the fishermen	Different levels
4	Perform mangrove reforestation	Obey the policies
5	Perform mangrove reforestation	Break the law
6	Perform mangrove reforestation	Different levels
7	Perform mangrove reforestation and listen to the fishermen	Obey the policies
8	Perform mangrove reforestation and listen to the fishermen	Different levels

From these scenarios, scenario 3 would be more close to reality as compared to the rest. For this research, each scenario was run for 5 years or 1800 time steps. This was done because the Bohol model developed is for demonstration purposes only. Consequently the results and analyses are samples rather than actual findings. The results will be presented and discussed in Chapter 5.

4.2.7 Discussion

Part of the process for modeling is to discuss it with other experts, the stakeholders and the policy-makers to validate the model and promote negotiation among the people involved in NRM. Due to financial limitations and local situations, this was not performed in this research. However, the following questions would have had helped in the validation of the model:

1) Is this what really happens? Are the tasks included in the model happens in reality or are they impossible to happen?
2) What aspect of the environment was missed or not included in the model but should have been there?
3) Which stakeholders should have been included and which should have not been included?
4) Could the model represent your present situation?

Other questions could also be asked in the discussion such as:
1) Would the model be useful to you? If yes, how would it be useful? If not, how can the model be improved for it to be useful?
2) Would you actually use the model?
3) What scenarios would you like to see in the model? What policy or program could help in improving the management of natural resources?

There are many more questions that could be asked and the list of questions stated above is not exhaustive. However, they could serve as take-off points for discussion of the model.

For analysis of the MAS model, several techniques were used and are listed below:
1) comparison of the charts produced using different scenarios
2) cross tabulation of land cover change
3) production of change-detection maps

The results and analyses of these techniques will be discussed in Chapter 5.

5 Analyses of the Implementation

5.1 Field Survey

The field survey was conducted using participatory techniques in acquiring information. For this research, individual and group interviews, as well as workshops, were conducted with the locals. The socio-political situation in the study area was the main consideration when conducting the interviews and workshops. At the barangay level, the locals were well organized. The locals were very cooperative with the researchers with the barangay captains participating in the activities. However, there seems to be lack of coordination between the communities and the LGU. Although the LGU claims to perform consultations with the different sectors of the municipality, the people of the community says that the LGU is consulting the wrong group of people to address a certain problem. Like the problem with the sanctuaries, the LGU claims to have consulted the barangay fisher folk groups and that these groups have supported the LGU's programs for declaring sanctuaries. Some fishermen are saying that the groups consulted do not have fishermen in them. This resulted to the fishermen having fewer areas where they could fish. Some don't even have areas where they could set out to go fishing because the coastline is lined with mangroves that have been declared as sanctuaries. A group of fishermen protested but were completely ignored and have been warned not to do any more protests. The research team for Bohol was warned not to mention anything regarding that issue for the possibility that the team might gain the ire of the mayor of the municipality and might jeopardize the research. With this in mind, joint workshops and interviews with people from various sectors would not be viable at the moment. Also, even if this were possible, because of the current situation the locals might not be as honest as they could be when they are face-to-face with LGU officials, and would just agree as to whatever the officials would say.

Gathering of data during the field survey was also difficult. The Comprehensive Land Use Plan of the municipality of Loon was unavailable in the LGU. The reason was that it was being reviewed, thus a copy cannot be made available. Also, as the second fieldwork was conducted after the barangay election, LGU officials were hard to find as they were busy with their obligations. Other data such as the PCRA of the municipality was also not available. A copy of the Coastal Environmental Profile of Northwestern Bohol had to be acquired from the Cebu City office of Bureau of Fisheries and Aquatic Resources since it was not available in both the municipal office of Loon and in the provincial capitol of Bohol. This problem of lack or unavailability of data is common in the Philippines based on this researcher's experience. Thus, the research team is forced to work with what data is available, however bad it is.

The workshops and interviews conducted were not sufficient enough to gather all the necessary information especially with regards to their decision-making rules. Also, there is the possibility that the interviewees and participants of the workshops were saying what they think the researchers would want to hear. Other techniques may be needed to verify the information being given by the locals.

5.2 Spatial data integration

Spatial data coming from different sources, having different scales, coordinates systems and quality, are one of main problems of spatial data integration. This is, however, unavoidable; thus having these kinds of data would require more time for processing. And because of the above-mentioned circumstances, overlaying of data inside a GIS is also not perfect. There are cases wherein the coastlines, or boundaries of the different layers of data do not correspond. The researcher has to choose which data layer to use as the base layer to which all coastlines (or boundaries) would be based upon and then use it as a "cookie cutter" for the rest of the data layers. In this research, since the PCRA map was obtained from a small-scale map and the topographic map was old and not up-to-date the satellite imagery was used as the "cookie cutter" for the coastlines. Also, experience and expert knowledge is needed when classifying satellite data. It would be an advantage if the researcher doing the classification of the satellite image has a very good knowledge of the area covered by the satellite image/s. Ground surveys on carefully selected areas are normally needed to gain knowledge of the study area. There are several techniques for selecting the areas for ground survey such as random sampling, wherein areas for ground survey are chosen randomly, or stratified areal sampling, wherein random sampling is performed on homogeneous clusters of each land use/cover. Other sources of data for verification may also be used such as up-to-date land cover/use maps and aerial photographs of the study area. Since aerial photographs are also expensive to acquire, it is suggested to us it only if it is available or could be acquired at a cheap price. It would be seen that the use of GIS and remote sensing technologies require experts when handling these data. Also, the necessary hardware and software for processing the data would prove be very expensive for municipalities, especially Loon which is a fifth class municipality, one of the poorest municipalities in the country. Tie-ups with academic institutions would be advantageous in these cases, with the academic institutions providing the necessary expertise and equipment, and the LGU and locals providing the necessary data to these institutions.

Another issue with data integration is the integration of the spatial data to the MAS modeling platform. In this case, the version of Cormas used in the model could handle vector data of MIF/MID (MapInfo Interchange Files) file format used by MapInfo, a commercial GIS software, and raster data of ASCII (American Standard Code for Information Interchange) file format as used by ArcView (It should be noted that the header data or information about the data of ASCII files differ from software to software.); thus, when importing data to Cormas, the spatial data must be converted to the files formats of the above-mentioned softwares. Although these softwares could handle file format conversion, knowledge of the structure of the above-mentioned file formats would prove to be valuable especially if these softwares are not available to the modeler. Also, when importing raster data into Cormas, the geographical position of the data is actually lost. This would mean that the original coordinates of the raster data must be remembered or recorded so that when it is time to put the data back to a GIS platform, the original coordinates could be inserted back to the data. When exporting raster data in Cormas, a dialogue box appears prompting the user to enter the original coordinates of the lower left corner (x,y), the size of the cell, and the value of “No Data” cells of the data set. These values will be written in the header of the ASCII file. If the user is familiar with the structure of the ASCII file being used by a specific GIS software, such as ArcView, the coordinates, cell size and value of “No Data” cells could be edited from outside Cormas.

5.3 MAS Modeling

MAS modeling in Cormas had its share of advantages and disadvantages. Being specifically designed for Natural Resource Management Applications, the methods built within Cormas were very useful and reduced the efforts in setting up the model itself. The other modules of Cormas, especially the modules for observing the model are useful for debugging the model. There are some issues, however, which need to be considered. First, the scale and coverage of the environment would be a concern to the modelers. In the model produced in this research, the environment is 188 x 224 in size, or 42,112 cells all in all, with each cell having 24 attributes (19 built within Cormas, 5 were added specifically for the model). This immensely reduced the speed of the simulation, which made it difficult to debug the model. Why not just use a bigger cell to reduce the dimension or number of cells of the environment? When using a bigger cell, a generalization of the environment takes place; thus some information are lost that may be important in the model. In the model for this research, for example, having a cell representing more than one hectare on the ground, the cells for the quarry would be lost in the generalization of the data.

To avoid problem of having a very large number of cells for the environment, a “synthetic” environment was temporarily used for programming and debugging. However, even if the “synthetic” environment had the same attributes as the original environment, the “synthetic” environment failed to completely capture the characteristics of the original environment; thus when the model was tested with the original environment, errors still occurred. These errors occurred due to the differences in scales of the model. The synthetic environment, although very much smaller than the environment for the study area (“Bohol environment”), had the same initialization as the Bohol environment, i.e. they had the same amount of resources. However, the number of agents in the synthetic environment is very much smaller than the number of agents in the Bohol environment. This occurred in a faster exploitation of the resources of the environment. A possible solution to this problem is to properly scale down the model in proportion to the size of the environment, and/or to put “failsafe” methods in the model to avoid the errors. Also, since the environment "behaves" or is constantly changing by itself, having complex cellular automata methods would slow the simulation even more. In the model for this research, the types and complexity of the cellular automata were simplified.

The study area is one municipality and the model had a large number of agents, a total of 1,375 agents at the beginning of the simulation. The speed of the simulation is not only dependent on the amount of agents, but also on the complexity of the activities of these agents. The more complex task each agent performs, the slower the simulation becomes. The complexity of the model has to be considered when designing the model. Questions such as "How many agents should be considered and what are the tasks they should perform?" and "How often are these tasks performed?" should be answered when designing the model.

The representation of time is also important in the model. The length of time a time-step represents in reality would limit the complexity of the tasks being performed in the model. In the model for this research, a time-step is equivalent to one day. This representation of time was chosen so that the day-to-day activities of the inhabitant could be modeled. This was done because one of the initial goals of the simulation model is to demonstrate to the locals how activities in one day affect the entire system. However, the shorter time a time-step represents, the bigger the room for the model to become more complex.

During the course of programming and debugging, the UML was simultaneously being modified to include new methods that were not considered before, and to allow modifications in the methods to make the simulation work properly and be more efficient. An issue that arises here is whether the methods of the model should be as similar to reality in terms of coding even if this would make the simulation slower, or to encode the model in such a way that the same tasks are performed but are coded in a different manner to make the simulation run faster or at least to make a particular activity work? In this research, due to the researcher's limited knowledge in programming in Cormas, the latter option was taken for one method, which is the changeJob method. Supposedly, this method is a part of the Inhabitant's methods. Instead, this particular method is included as one of the methods at the control of the model. Modelers, however, insist that a modeler should follow "reality" as much as possible.

To check the consistency of the model, 3 simulations were performed. The results of the simulations were recorded as Microsoft Excel worksheets. Several charts of the results of the simulation are shown below.

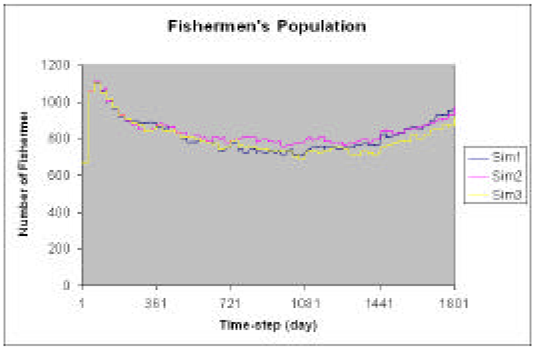

Figure 5.1 Fishermen's Population

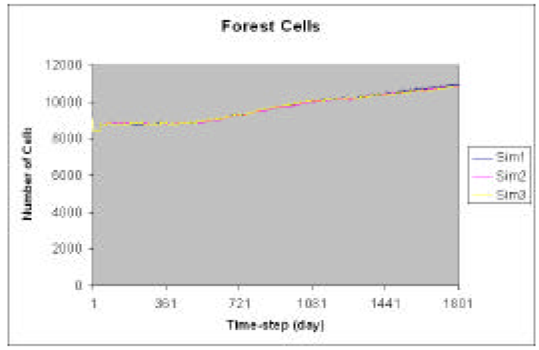

Figure 5.2 Forest Cells

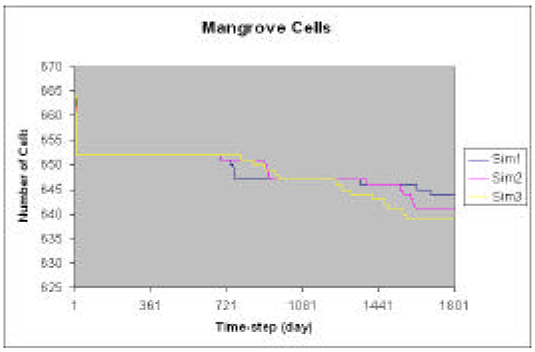

Figure 5.3 Mangrove Cells

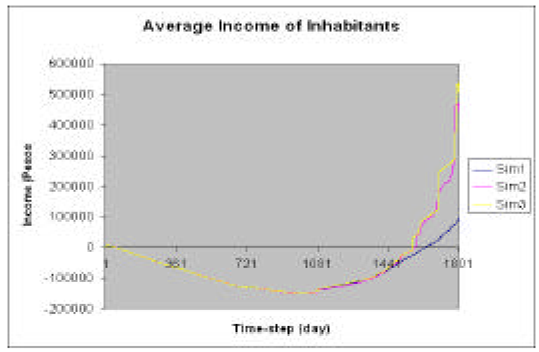

Figure 5.4 Average Income of Inhabitants

From the figures shown above, by visual inspection, it could be seen that the charts for Fishermen's Population and Forest Cells are very much similar, which would be a desirable result for consistency. Having a consistent model would mean that a simulation of a model would be similar to other simulations of the same model; thus there is more confidence in its interpretation. However, looking at the chart for Mangrove cells, there is already some disparity in the trend of the lines near the end of the simulation, especially for the third simulation. Moreover, in the chart for Average Income of Inhabitants, there is a large disparity at the last year of the simulation between simulation 1 and simulations 2 and 3. It could be said that the model is inconsistent in these aspects. These differences may be brought about by the methods using the random function as part of its decision-making process. Or, it could be said that the system itself is unpredictable, doesn't have a pattern at all, or may have several stable states. At this point, these interpretations are only samples and should not be taken as is for the mere fact that there were only three simulations that were performed to check the consistency of the model and that the results are inconclusive. Only three simulations were performed because it is only used to demonstrate one of the many techniques in verifying a simulation model. More simulations should be performed and the results compared to better understand the behavior of the model. Charts of other aspects of the model for its verification are found in the appendices (Appendix C).

5.4 Simulation

The scenarios to be discussed in this section were developed on the basis of the current situation of the study area. Two factors were considered: the LGUs role, wherein the LGU performs mangrove reforestations while ignoring the complaints of the fishermen, and the inhabitants' attitude towards policies regarding sanctuaries. As the model developed for this research is only a shell or a skeleton of a MAS model for NRM, the discussion is only limited to the results as samples of how to interpret the results of the scenarios. In Cormas, results of scenarios could be save in several ways, namely charts, MS Excel file, ASCII text file. Also the environment could be exported in several ways, as a MapInfo interchange File, as a raster file for Idrisi, and as ASCII file for ArcView. By exporting the environment in ASCII file format, the environment is saved into several layers depending on the number of attributes to be saved. In this research, the results of the simulations were stored in an MS Excel file and the environment was saved in ASCII file format. Since there are 14 probes set-up for the model, not all results would be presented in this section. Several charts would only be selected for illustration.

To determine the effect of the attitude of the inhabitants, the scenarios were grouped according to the task of the LGU to better show the effect of the different attitudes of the inhabitants. The following figures were obtained to illustrate its effects:

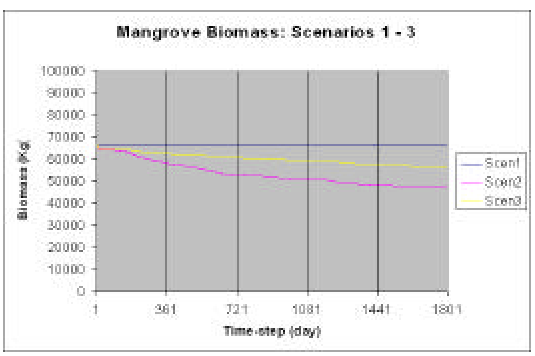

Figure 5.5 Mangrove Biomass: Scenarios 1 – 3

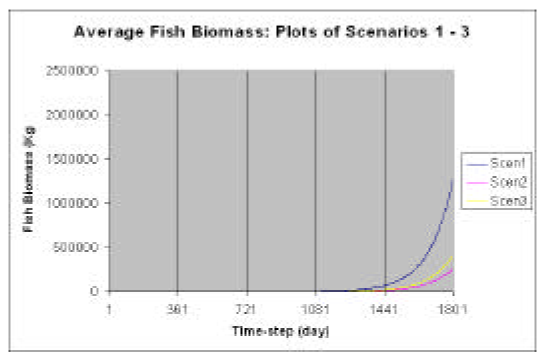

Figure 5.6 Average Fish Biomass: Scenarios 1 – 3

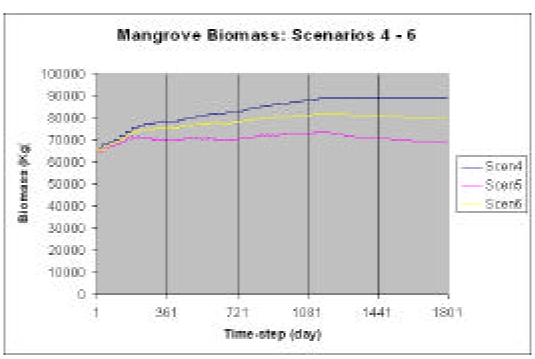

Figure 5.7 Mangrove Biomass: Scenarios 4 – 6

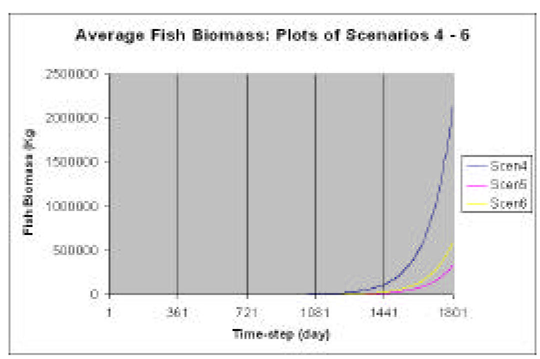

Figure 5.8 Average Fish Biomass: Scenarios 4 - 6

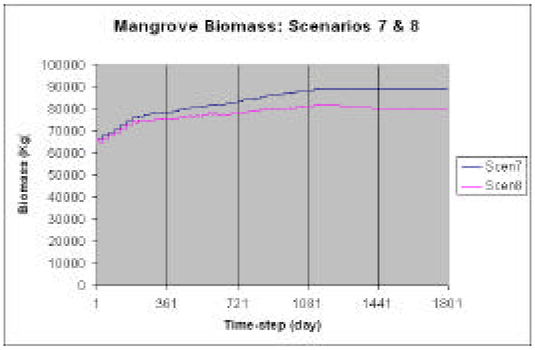

Figure 5.9 Mangrove Biomass: Scenarios 7 and 8

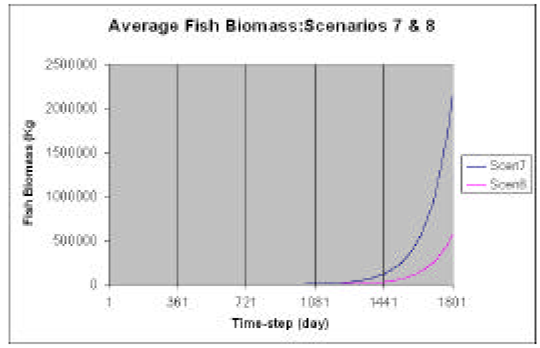

Figure 5.10 Average Fish Biomass: Scenarios 7 and 8

Inspecting Figures 5.5 it could be observed that in scenario 1 the decrease of mangrove biomass is slower as compared to scenarios 2 and 3. Scenario 1 is where the LGU is ignoring the fishermen's complaints and is not performing mangrove reforestation. All the inhabitants, however, are following the policy of not engaging in any activity inside the mangrove areas. The poison released from fishponds brought about the slight decrease of mangrove biomass. Looking at figure 5.6 we could see that the average fish biomass in the fishing areas has a higher rate of increase as compared to the other two scenarios. We may interpret this as a positive effect of the slow decrease of mangrove biomass. This trend could also be seen in scenarios 4-6 and 7-8. Scenario 2 and 5, wherein all the Inhabitants break the law, it could be seen that the rate of increase in the mangrove biomass and average fish biomass is lower than the other scenarios. As for scenario 3, 6 and 8, wherein the inhabitants have a varied susceptibility in breaking the law, the rates of growth for both mangrove and fish are found in between the other two scenarios. Its effect in terms of income of the fishermen the following charts were obtained:

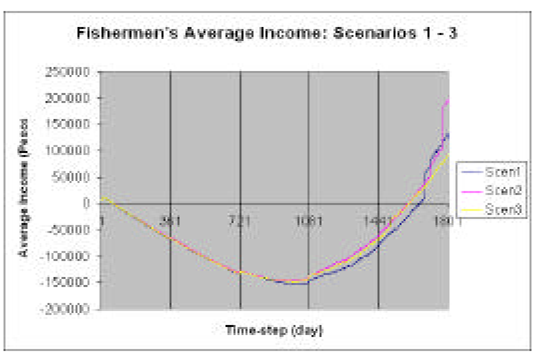

Figure 5.11 Fishermen's Average Income: Scenarios 1 - 3

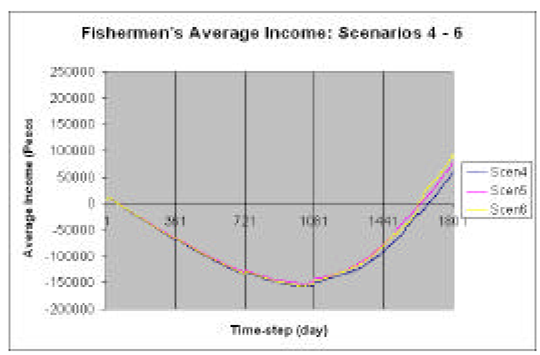

Figure 5.12 Fishermen's Average Income: Scenarios 4 - 6

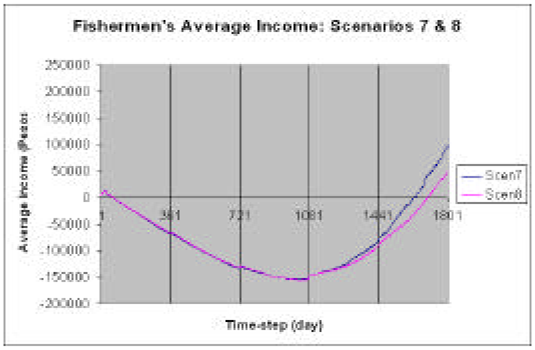

Figure 5.13 Fishermen's Average Income: Scenarios 7and 8

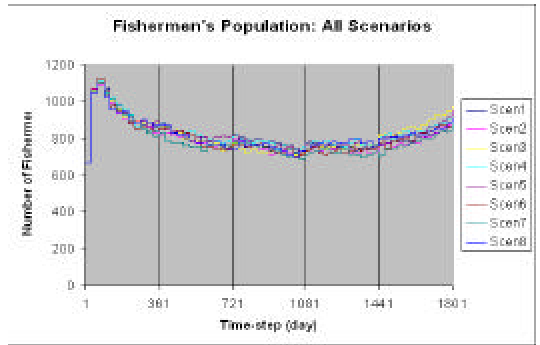

Figure 5.14 Fishermen's Population: All Scenarios

The figures above for the average income of the fishermen show little difference between the scenarios. However, a trend could be seen in all the scenarios. At the end of the 3rd year, after experiencing a steady decline in income, the inhabitants start to recover. Going back to Figure 5.6, 5.8 and 5.10, at the end of the third year (or the beginning of the fourth year), it could be seen that the amount of fish is starting to recover. If we look at Figure 5.14, it could be seen that it is also during this time that the number of fishermen is at its second lowest (the beginning of the simulation was the number of the fishermen at its lowest) and is starting to increase. As for the sudden increase in the population of the fishermen, it could be seen from Figure 5.4.11 that the increase of fishermen may be due to the sudden decrease of farmers.

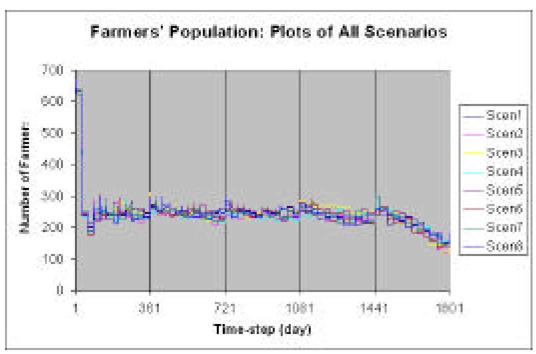

Figure 5.15 Farmers' Population: All Scenarios

Analyzing the effect of the LGUs activities, the results of the scenarios were grouped according to the attitudes of the inhabitants. The following figures were obtained:

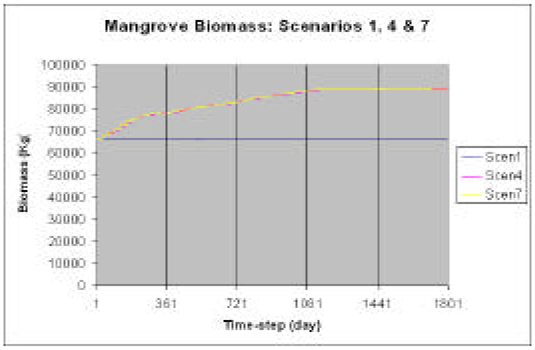

Figure 5.16 Mangrove Biomass: Scenarios 1,4 & 7

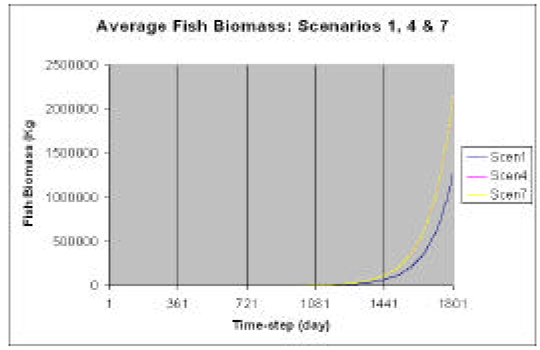

Figure 5.17 Average Fish Biomass: Scenarios 1, 4 & 7

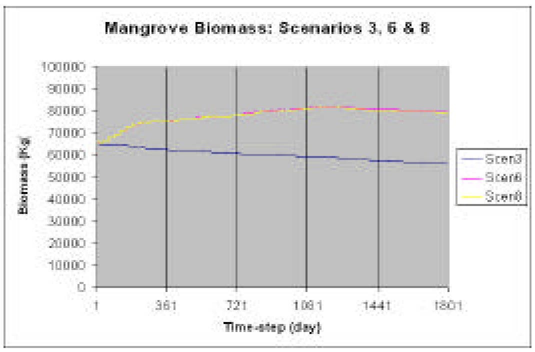

Figure 5.18 Mangrove Biomass: Scenarios 3, 6 & 8

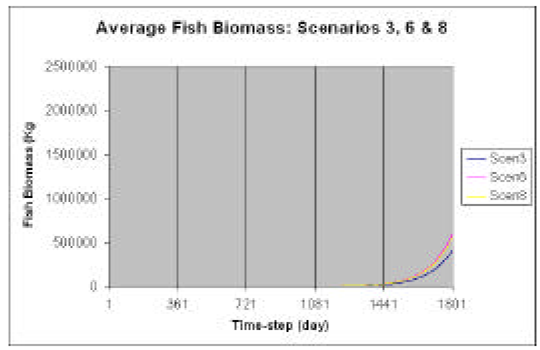

Figure 5.19 Average Fish Biomass: Scenarios 3, 6 & 8

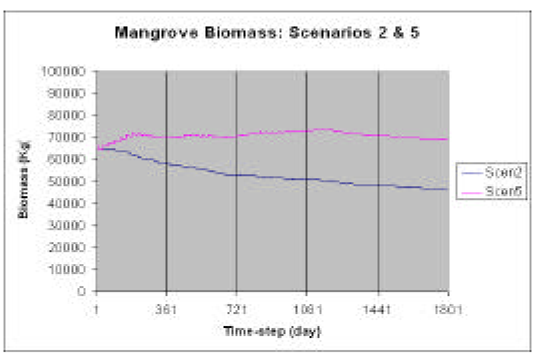

Figure 5.20 Mangrove Biomass: Scenarios 2 and 5

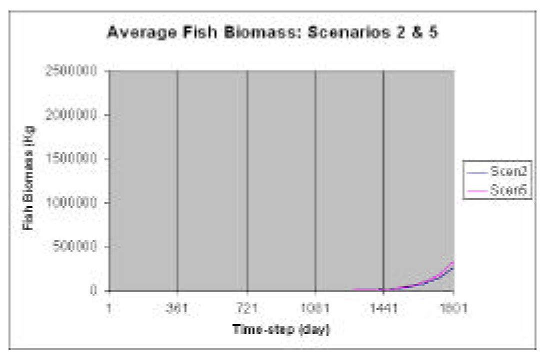

Figure 5.21 Average Fish Biomass: Scenarios 2 and 5

In Figure 5.16 it could be clearly seen the big difference between scenarios 4 and 7 with scenario 1. It should be recalled that in scenarios 4 to 8, the LGU is doing mangrove reforestation activities. Going to Figure 5.17, it could be seen that, again, scenarios 4 and 7 have a higher rate of growth as compared to scenario 1. The same trend could be observed from Figures 5.18 to 5.20. It could be said that the mangrove reforestation efforts of the LGU lead to a higher rate of growth for fish stock.

Now that the results of the simulation have been shown using charts, what about the environment? How could the environment be used for analyses? To illustrate how spatial data could be analyzed, two basic techniques in GIS/RS will be used, namely cross-tabulation and change-detection. The results of a cross-tabulation is a cross table containing information as to what type of land use / cover has changed and what has it changed into from the former state to the latter state. The result of a change-detection process is a map indicating areas that have changed. In ArcView this process is performed by means of a map query, wherein a comparison of the initial and the final state of the environment in the simulation is made, by means of the question "Which cells of the initial state have a different value in the final state?" An answer of true or false is returned for every cell. In this case, it will show which areas have changed after five years. Examples of the results of these techniques are given below.

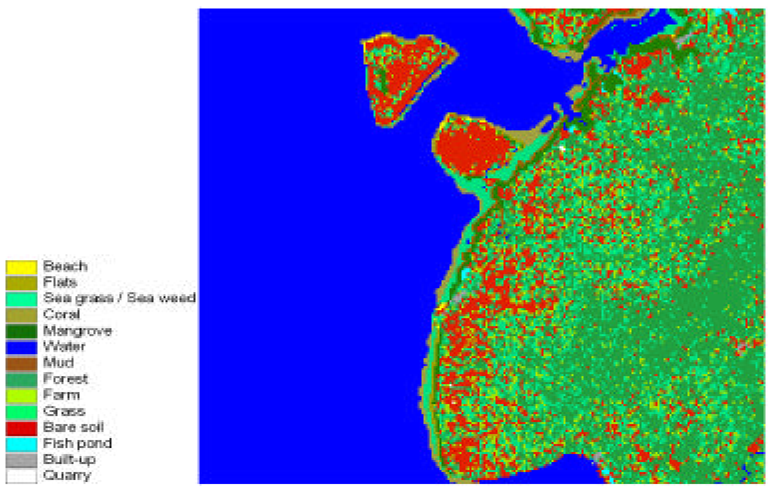

Figure 5.22 Bohol: Initial State

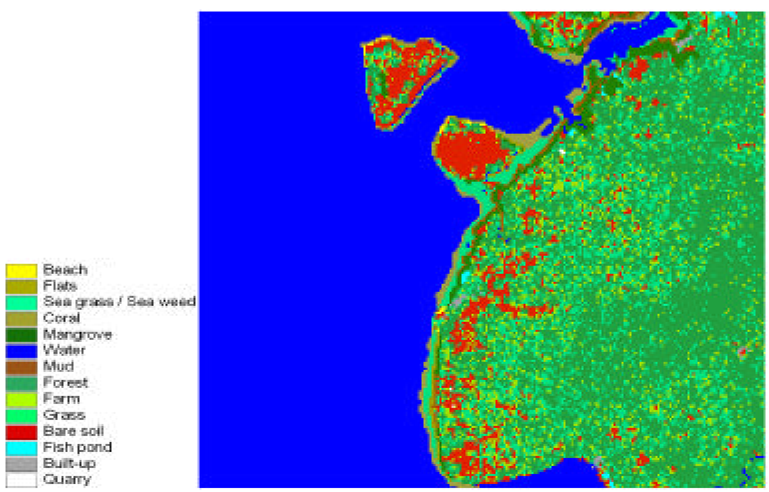

Figure 5.23 Bohol: Final State (Scenario 3)

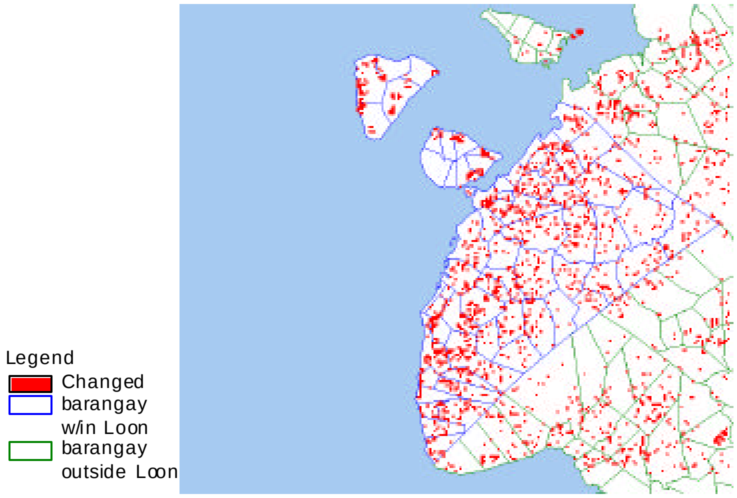

Figure 5.24 Change Map: Initial State vs. Scenario 3

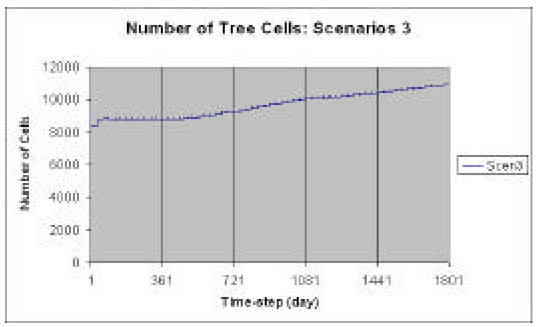

Figure 5.25 Number of Tree Cells: Scenario 3

From Figure 5.24 it could be seen that a lot of changes have had happened in the study area after running the simulation model for 5 years or 1800 time-steps. However, to determine exactly what has changed over the last five years, the cross-tabulation (as given in Table 5.1) is needed. How is a cross-tabulation interpreted? The values on the diagonal are the cells that didn't change. The values from top to bottom are the values of the final state, while the values from left to right are the values of the initial state. For example, the intersection of the column for forest and the row for bare soil has a value of 1,973. This means that 1,973 bare soil cells from the initial state has changed into forest cells in the final state. Adding the values on the column for forest, it would yield a value of 10,968 cells. Adding the values on the row for forests it would yield a value of 9,061 cells. Figure 5.25 would confirm these values. The change-detection maps of the other scenarios plus their associated cross tabulations would be included in the appendices (Appendix D).

The results of the simulations may seem to be contrary to what is expected such as the expansion of forest areas and recovery of the fish stock. This may be due to the oversimplification of the methods with regards to the growth of the trees and reproduction of fish, or the assumptions made for these methods were wrong. More appropriate methods for the growth of these resources should be used in the refinement of the Bohol model.

The techniques illustrated above are just few of the many types of spatial analysis that could be performed on spatial data. Other techniques such as landscape pattern analysis could also be useful, however, this will no longer be covered in this research.

Table 5.1 Cross Tabulation between Initial State and Final State (Scenario 3) of Bohol Environment

	Final State (Scenario 3)															
	Land Use / Cover	Beach	Flats	Sea grass	Coral	Mangrove	Water	Mud	Forest	Farm	Grassland	Bare	Fishpond	Built-up	Quarry	Total
Initial State	Beach	31	0	0	0	0	0	0	0	0	0	0	0	0	0	31
	Flats	0	172	0	0	0	0	0	0	0	0	0	0	0	0	172
	Sea grass	0	0	566	0	0	0	0	0	0	0	0	0	0	0	566
	Coral	0	0	0	537	0	0	0	0	0	0	0	0	0	0	537
	Mangrove	0	0	0	0	644	0	20	0	0	0	0	0	0	0	664
	Water	0	0	0	0	0	19804	0	0	0	0	0	0	0	0	19804
	Mud	0	0	0	0	0	0	209	0	0	0	0	0	0	0	209
	Forest	0	0	0	0	0	0	0	8995	63	0	3	0	0	0	9061
	Farm	0	0	0	0	0	0	0	0	2015	0	0	0	0	0	2015
	Grass	0	0	0	0	0	0	0	0	0	4695	0	0	0	0	4695
	Bare	0	0	0	0	0	0	0	1973	27	0	2241	0	0	0	4241
	Fishpond	0	0	0	0	0	0	0	0	0	0	0	55	0	0	55
	Built-up	0	0	0	0	0	0	0	0	0	0	0	0	56	0	56
	Quarry	0	0	0	0	0	0	0	0	0	0	0	0	0	6	6
	Total	31	172	566	537	644	19804	229	10968	2105	4695	2244	55	56	6	42112

6 Insights and Recommendations

6.1 Insights gained in this research

Potential uses of MAS, RS and GIS in NRM

In this research, one of the goals of the research is to be able to show some of the potential uses of MAS modeling in NRM. One possible use of MAS models is as a tool for learning. How can this be used as a learning tool? People may not have a clear picture about their environment. They may have knowledge about certain portions of it, but they may not know all the details about their environment. They may also be unaware of how individual decisions may affect their environment. By being able to accommodate maps in the simulation model, it acquires the advantage of being able to visually communicate the situation of an environment, though not entirely, but the most prominent aspects of it, just as what GIS maps and maps derived from satellite images can do. As what happened with the interview with the mayor of Loon, by showing him the satellite image of his municipality, he was able to see immediately how large the coverage of the fishponds are as compared to the size of the municipality proper. By means of the satellite imagery, the mayor was immediately able to infer an aspect of his municipality that he wasn't aware before by just looking at the satellite image. Also, from the workshops conducted with the local communities, by seeing their community in a map, they were able to gain some aspects of their community, such as how far it is from the municipality proper as compared to other communities, how much trees are covering their community, etc. This exercise is like looking outside the box for the first time, imagining oneself being confined inside the box the whole time prior to this exercise. One could just imagine how much he or she could learn by seeing his environment from another point of view – from outside the "box." This is an advantage shared by spatially-explicit models, such as MAS, GIS and RS models. Why not just use RS/GIS modeling then? As models produced with RS and GIS are only static or "snapshots" of an NRM situation, they may not be enough to capture the behavior of an NRM system, especially the human factor. With a MAS model, human activities and their impact on the natural resources could be modeled and demonstrated visually. To help them understand the MAS model, UML diagrams may be used. With proper explanation, UML diagrams may be useful in communicating the MAS model to other people who are not necessarily programmers or modelers themselves. With these UML diagrams, the structure and content of the MAS model could be explained more easily without going through its source codes. And by showing the MAS simulation model, similar to watching a home movie, the actors of the model (the stakeholders and policy-makers) could see "themselves" moving in their environment. As the simulation progresses, they could observe and relate their activities with the changes in the supply of their natural resources and also observe and relate how their actions could change their environment. From what they could learn from watching a "movie" about themselves and their possible future – the result of the simulation, they could develop new strategies or come up with scenarios that may lead to sustainable NRM management. And this leads us to another potential of MAS models.

MAS models could foster the development of scenarios or strategies for NRM learning from the MAS model simulation. Moreover, these scenarios or strategies could be tested on the existing MAS model. By being able to test these strategies, the set of strategies could be filtered or sorted out depending on their viability; thus the costs of implementing new strategies could be minimized. Based on the results of the simulation models in this research, it could be seen that by varying some parameters in the model, namely the stakeholders' attitude towards policy and LGU's role in NRM, the simulations produced varying results. Although the model created in this research is only a skeleton for future MAS models, it was able to demonstrate how scenarios or strategies for managing natural resource could benefit or detriment the system. Take for example the mangrove reforestation task of the LGU. Comparing the results of scenarios without mangrove reforestation with the scenarios with mangrove reforestation, the amount of fish available is greater and that the rate of increase is faster. This kind of example shows that by varying the activities of the agents in the MAS model, the amount of resources that could be exploited in the MAS model would also vary. The stakeholders and policy-makers may be able to relate the results of the strategies in the MAS model with their own NRM situation.

What then would be the role of RS and GIS in MAS modeling for NRM? Satellite imagery, when properly processed using RS techniques, may be an important source of data, especially when there is lack of available spatial data in the study area. Satellite imagery could also be used to verify and update existing data. GIS, on the other hand, could be used to efficiently integrate data acquired from satellite images with other spatial data from other sources, before importing them to be used by the MAS model. After using the MAS model for simulation, the resulting spatial information from the model could be exported back to the GIS/RS software and effectively analyzed using GIS/RS techniques. By using the digital maps, changes could be identified and quantified over the study area. Emerging spatial patterns may also be observed from these digital maps. Plans, zoning of areas, and new strategies to ease the problems in NRM could be produced based on the results of the simulations and spatial analyses.

With all the activities involved in the MAS modeling process, the process itself may contribute greatly in the learning process for the researchers, stakeholders and policy-makers themselves. The participants of the modeling process may be able to gather or learn ideas about the NRM situation that may increase the initiative and involvement of the participants in managing their environment and natural resources. The experiences and lessons gained from the process may also be used in the implementation of the MAS modeling process with NRM situations of other study areas. Probably, there may be cases wherein the MAS modeling process would have the same, or have greater importance than the MAS model itself.

Potential problems in the use of MAS, RS and GIS for NRM

Workshops, trainings, group and individual interviews may be venues to get the local communities and the local government familiarized with the technologies used in this research. This could help them understand the importance of these technologies in their NRM situation. Also, from these venues, it may possible to see the receptiveness of the local communities and the local government to new technologies. It would be hard to gain support in applying the tools presented in this research in their own NRM situation they are not open to new technologies, probably because of the possible costs involved in using these technologies.

It is true that MAS, RS and GIS technologies are very expensive to use. These tools rely heavily on expertise and expensive data. Hiring experts for MAS modeling would be problematic especially if there is only a very limited budget for it. If the MAS model is going to be set-up locally in the study area, software and hardware costs for storing and running the different applications for MAS modeling would be problematic. Although some programming platforms, such as Cormas, are downloadable for free over the Internet, other programming languages are quite expensive. Also, commercial softwares for RS and GIS are also rather expensive. There are, however, GIS and RS softwares available in the Internet that are free, although they have very limited facilities for data handling, processing, manipulation and analysis. Linkages with academic institutions, government offices and non-government organizations would help in alleviating these problems. Agreements with institutions like universities or colleges, government offices such as the LGU and DENR, and NGOs for data and field survey equipment may help reduce the overhead costs of acquiring the necessary data and equipment for data gathering.

As what was experienced in this research, the local communities and the LGU seem to be supportive of MAS modeling. They actively participated in the interviews and workshops that were conducted. They also were able to draw ideas on how these technologies could help them. In this case, further studies on MAS modeling, especially in the case of the municipality of Loon, Bohol may prove to be fruitful.

6.2 Further research on MAS, GIS, RS and Participatory Approaches

Not every aspect of MAS modeling, GIS, RS and participatory approaches has been covered in this research. There is much more that is needed to be explored in MAS modeling, from its conception to its application to NRM situations. In this research techniques for eliciting information from the stakeholders were only limited to individual and group interviews and workshops. However, there are many more ways of eliciting information. One method that has been used in the process of MAS modeling is the use of role-playing games. In this case, role-playing games have to be modified to fit the local situation for it to be accepted by the players of the game, which are the stakeholders and/or policy-makers.

The coverage of the study area in this research limited the number of kinds and complexity of processes included in the model. Having a very large grid size for an environment in CORMAS, with 188 rows and 224 columns, a lot of simplifications were applied to the processes in the MAS simulation model, some were even no longer included in the model such as the effect of water current and fish migration patterns. Having a large grid size slows down the operation of the simulation model making it very hard to debug. Although a way to avoid this problem is by using a smaller environment for testing, problems were encountered with having a "synthetic" environment as discussed in Chapter 5. If the grid size of the study area is large (as in the case of the Bohol model developed for this research) it is recommended that area be divided into smaller test or pilot areas, wherein a model for each of the study area would be developed and the results of these "smaller" models could be used as input to an overall model for the whole study area. Processes that were not considered due to the inability of the model to represent them and their dynamics at the scale of the model, both spatially and temporally, could now be considered in these smaller models.

Since the model was built to be used for demonstration purposes only, further studies on its structure and contents is needed before it could actually be used in actual NRM situations. It is important that the model is validated before its results could be reliable. In this research, validation of the model was not performed with the stakeholders and policy-makers so it is suggested that, for further research, this model, or any other MAS model for that matter, should be validated with the participants of a participatory NRM discussions. Also, in this research, the coastal environment was used as the study area. However, it should be said that the model, or the methodology for MAS modeling proposed in this research is not only limited to coastal environments alone. In cases wherein the coastal environment is no longer the study area, the structure and components of the MAS model has to be modified to fit its intended application.

There are still a lot of areas that can be explored in Cormas. As mentioned in Chapter 4, Cormas can also handle vector data besides raster data. The structure of the class for the elementary spatial entities has built-in attributes for explicitly defining the topology of polygons such as its neighborhood. Since Cormas was built with minimal GIS processes, spatial analysis using GIS softwares outside Cormas is needed. Cormas has an ability to import and export raster and vector data but using only limited software formats. It would be interesting to explore the linkage between Cormas and other GIS softwares; that is to make import and export processes more simple for the user. The development of the Cormas platform is an on-going process, adding new modules or facilities for data integration and analysis as needed in a wide variety of applications. GIS/RS modules could be made for Cormas to handle basic GIS/RS analysis techniques without having to use another software to perform these processes.

The choice for languages and platforms for programming MAS simulation models should not be limited to Cormas alone. Although Cormas has been designed for NRM applications, there are other platforms and programming languages that could be used for programming MAS models. As mentioned in Chapter 2, there are many more platforms and languages available for MAS modeling. By programming MAS models using the more popular programming languages such as Java and C++, the model could be programmed and debugged by more people experienced in these languages given enough understanding of the MAS model. Also, if the modeler finds platforms already built for NRM applications insufficient for his/her purpose, s/he can use other languages s/he is more comfortable with, and possibly, could add more analysis techniques that s/he feels is needed in his model or application but is not available in other platforms.

GIS and RS techniques used for analyses in this research were only basic and much more could be done in explaining the spatial distribution of different land covers. An example of other analyses techniques is the use of land cover pattern indices. Land cover pattern indices are used to explain quantitatively the configuration of different spatial distributions. One of its more popular uses is the quantification of the fragmentation of forests. Fragmentation is defined as “disruption of continuity in a pattern or process” (Meffe and Carol, 1994 as cited by Echavarria, 1996). A big contributor of forest fragmentation is human activities such as construction of roads and settlements. (Echavarria,*Ibid*.).

The most important aspect of the MAS modeling process that this research was not able to accomplish was to validate the Bohol Model, the MAS model created for this research, with the local communities and the LGU. Validation is important because the model has to be made reliable before it can be used in an actual NRM situation. And since the validation of the Bohol model was not accomplished, it has not been introduced to the actual NRM situation of Loon, Bohol. This may be a good direction to follow for a continuation of this research.

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Appendices

Appendix A: Examples of Cormas Source Codes of the Bohol Model

Control of Scenario 8

The source codes given below correspond to the control of scenario 8 of the Bohol model. These codes are the exact translation of the sequence diagram (Figure 4.26) found in Chapter 4. The first line is the name of the method. The second line corresponds to the declaration of temporary variables in the method.

```
stepLGUListenRandom: t
| x y z t7 |
self theWeathers do: [:a | x := a weatherGen].
self theInhabitants do: [:a | a weather: x].
t7 := OrderedCollection new.
t7 addAll: self theInhabitants.
t7 addAll: self thePoisons.
self stepEntities: t7.
z := (Cormas mixt: (self theInhabitants select: [:a | a occupation = #pondworker and: [a patch res1 = -1]])) asOrderedCollection.
z isEmpty
	ifFalse:
		[z do:
			[:t2 |
			self createPoison: t2.
			t2 wealth > 0 ifTrue: [t2 sendPressure].
			t2 readMail].
			z do: [:t2 | self changeJob: t2]].
self modelTimer = 30
	ifTrue:
		[self jobHiring: (Cormas selectRandomlyFrom: (0 to: 1)).
		y := (Cormas mixt: (self theInhabitants select: [:a | a occupation = #farmer or: [a occupation =
		#fisherman]])) asOrderedCollection.
		y do:
			[:t1 |
			t1 wealth > 0 ifTrue: [t1 sendPressure].
			t1 readMail].
		y do: [:t5 | self changeJob: t5].
		self theBgyFisherfolks do: [:a | a step].
		self theLGUs do: [:a | a step].
		self modelTimer: 1]
	ifFalse: [self modelTimer: self modelTimer + 1].
self modelTimer2 = 360
	ifTrue:
		[self populationGrowRandom.
		self modelTimer2: 1]
	ifFalse: [self modelTimer2: self modelTimer2 + 1].
self stepSynchronously: t.
self thePoisons removeAllSuchThat: [:t6 | t6 isDead].
self updateData: t.
```

changeJob Method

This method is a direct translation of the changeJob activity diagram (Figure 4.25) given in Chapter 4. The changeJob method is found in the control of the Bohol model and is applied to the Inhabitants. The first line corresponds to the name of the method and the second line corresponds to the declaration of temporary variables of the method.

```
changeJob: a
| x m |
```

```
x := #(#farmer #fisherman) asOrderedCollection.
a occupation ~= #pondworker ifTrue: [x remove: a occupation].
a wealth < 0
	ifFalse:
		[a occupation = a pressure
			ifFalse:
				[Cormas random < a character
					ifTrue:
						[(a occupation = #pondworker and: [a pressure = #farmer])
							ifTrue:
								[self changeFromPondworkerToFarmer: a].
						(a occupation = #pondworker and: [a pressure = #fisherman])
							ifTrue: [self changeFromPondworkerToFisherman: a].
						(a occupation = #farmer and: [a pressure = #fisherman])
							ifTrue: [self changeFromFarmerToFisherman: a].
						(a occupation = #fisherman and: [a pressure = #farmer])
							ifTrue: [self changeFromFishermanToFarmer: a].
						(a occupation = #farmer and: [a pressure = #pondworker])
							ifTrue: [self pondHiring > 0
								ifTrue: [self
							changeFromFarmerToPondworker: a]].
						(a occupation = #fisherman and: [a pressure = #pondworker])
							ifTrue:
								[self pondHiring > 0 ifTrue: [self
								changeFromFishermanToPondworker: a]]]]]
	ifTrue:
		[a occupation = #pondworker
			ifTrue:
				[Cormas random < a character
					ifTrue:
						[a occupation = a pressure
							ifFalse:
								[a pressure = #farmer ifTrue: [self
								changeFromPondworkerToFarmer: a].
								a pressure = #fisherman ifTrue: [self
								changeFromPondworkerToFisherman: a]]]
					ifFalse:
						[self jobHiring > 0
							ifTrue:
								[a myGroup deleteComponent: a.
								m := (Cormas selectRandomlyFrom: a
								myPond) theCSE at: #Fishpond.
								m vacancy: m vacancy + 1.
								a myPond do:
										[:n |
										n res1: 0.
										n res2: -1].
								a migrate.
								self jobHiring: self jobHiring - 1.
								self pondHiring: self pondHiring + 1]
							ifFalse:
								[Cormas random < a character
									ifTrue:
										[(Cormas
										selectRandomlyFrom: x)
										= #fisherman
											ifTrue: [self
											changeFromP
											ondworkerToFi
											sherman: a]
											ifFalse: [self
											changeFromP
											ondworkerToF
											armer: a]]]]]
			ifFalse:
				[self pondHiring > 0
					ifTrue:
						[a occupation = #farmer
							ifTrue: [self changeFromFarmerToPondworker: a]
							ifFalse: [self changeFromFishermanToPondworker: a]]
```

```
ifFalse:
    [Cormas random < a character
        ifTrue:
            [a occupation = a pressure
                ifFalse:
                    [a pressure = #farmer
                    ifTrue: [self
                    changeFromFishermanT
                    oFarmer: a].
            a pressure = #fisherman
                ifTrue: [self
            changeFromFarmerToFisherman: a]]]
        ifFalse:
            [self jobHiring > 0
                ifTrue:
                    [a migrate.
                    self jobHiring: self
                    jobHiring - 1]
                ifFalse:
                    [Cormas random < a
                    character
                        ifTrue:
                        [(Cormas
                        selectRandoml
                        yFrom: x) =
                        #fisherman
                        ifTrue: [self
                        changeFromF
                        armerToFisher
                        man: a]
                        ifFalse: [self
                        changeFromFi
                        shermanToFar
                        mer: a]]]]]]]
```

goSlash Method

This method is only used by a farmer inhabitant. This is the exact translation of the goSlash activity diagram (Figure 4.22) in Chapter 4 within Cormas. The first line corresponds to the name of the method and the second line is the declaration of temporary variables of the method.

```
goSlash
| x y |
self myCrop > 0
    ifTrue:
        [y := (16 - self myFarm res1) / 16 * 0.0001 * self myCrop.
        self myCrop: self myCrop - y].
self weather = #good
    ifTrue:
        [x := self checkForLandToTill.
        x = nil
            ifTrue:
                [self findFarm.
                self myFarm = nil
                    ifTrue:
                        [self goQuarry.
                        self rocks < 20
                            ifTrue:
                                [self findAnotherFarm.
                                self myFarm = nil
                                    ifTrue:
                                        [Cormas random < self
                                        character
```

```
                                                                                                                    ifTrue: [self
                                                                                                                    migrate]]
                                                                                                ifFalse: [self slashArea]]]
                                                        ifFalse: [self slashArea]]
                                        ifFalse:
                                                [self myCrop > 0
                                                        ifTrue:
                                                                [self timer = 90
                                                                        ifTrue: [self harvest]
                                                                        ifFalse:
                                                                                [self timer: self timer + 1.
                                                                                Cormas random > self lawAbiding
                                                                                        ifFalse: [self goQuarry]
                                                                                        ifTrue:
                                                                                                [Cormas random < 0.2
                                                                                                ifFalse: [self
                                                                                                gatherWood] ifTrue: [self
                                                                                                goQuarry]]]]
                                                        ifFalse:
                                                                [self myFarm res2 = 360
                                                                        ifTrue:
                                                                                [self myOldFarm add: self myFarm.
                                                                                self myFarm state: 400.
                                                                                self myFarm: nil]
                                                                        ifFalse: [self plant]]]]
                ifFalse:
                        [self stayHome.
                        self myFarm = nil ifFalse: [self myFarm res1: self myFarm res1 - 0.1].
                        self myCrop > 0
                                ifTrue:
                                        [self myCrop: self myCrop - (Cormas selectRandomlyFrom: (10 to: 100)).
                                        self myCrop < 0 ifTrue: [self myCrop: 0]]].
                                        self myFarm = nil ifFalse: [self myFarm res2: self myFarm res2 + 1].
self updateWealth
```

Appendix B: Lists of Assumptions in the Bohol Model

Environment

Initial Values of Cells

Land Cover / Use	res1	res2
Quarry	20 million cubic meters	N/A
Forest	100 Kg of tree biomass	N/A
Water	50 Kg of fish	N/A
Mangrove	100 Kg of fish	100 Kg of mangrove biomass
Sea grass / sea weed	100 Kg of fish	100 Kg of sea grass / sea weed biomass
Corals	100 Kg of fish	100 Kg of coral biomass
Mud	50 Kg of fish	N/A

Methods:

1) fishCA – the growth of fish stock of a cell is 0.05% of its own fish stock and 0.05% of the total fish stock of its neighborhood.
2) ForestCA – the growth of tree biomass of a cell is 0.01% of its own and its neighborhood tree biomass if it's a forest cell. Growth is 0.005% of its own and its neighborhood tree biomass if it's a forest cell. Bare land changes to forest land if it has at least 20 Kg tree biomass.

Social Agents

Inhabitants

Type	Assumptions
(all)	- daily expenses of inhabitant is between 200 and 300 pesos - limestone quarry is valued at 5 pesos/m^3
Farmer	- harvests usually every three months, depending on weather conditions - fallows land every year - plants 100 Kg of crop - earns 75 pesos/Kg of crop - quarries up to 25 m^3/day of limestone - gathers between 1 to 3 Kg of wood in mangrove areas and sells them at 100 pesos/Kg - productivity of a farm cell starts at 16 units and decreases by 0.5 units per harvest and 0.1 units during bad weather. The amount of loss of crop is given by the equation: $L = \frac{16-p}{16} * 0.0001 * c$, Where: L is the loss in Kg p is the productivity c is the amount of crop in Kg
Fisherman	- fishes up to 15 Kg/day of fish, 2 Kg of which is for personal

	consumption - quarries up to 5 m^3/day of limestone - gathers shellfish between 8 to 10 Kg/day for personal consumption - fish is valued at 80 pesos/Kg
Pondworker	- earns a salary of 4000 pesos/month - has a commission of 66 centavos/10 Kg of harvest
OFW	- salary is constant at 10,000 pesos

Poison

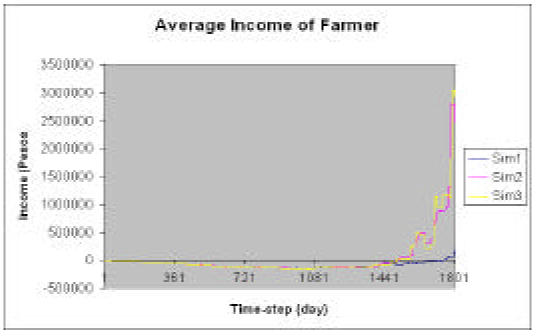
- has an initial strength of 8 to 10 units, and is reduced by 1 unit per day
- moves on water, coral, sea grass / sea weed, mangrove or mud cell where there are at most 3 poison agents
- reduces 0.1% of the total amount of resources in a cell

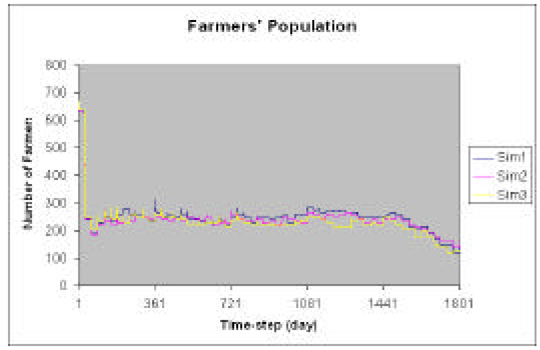
Passive Object

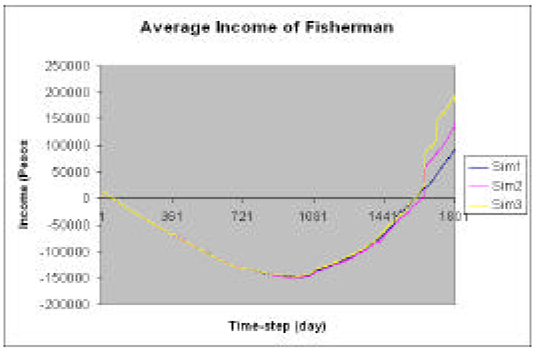
Weather

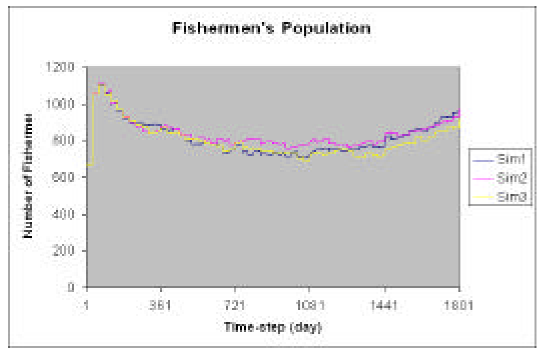
Month	Probability of having bad weather
December – February	1%
March – April	0.1%
May	0.7%
June – August	10%
September – October	7%
November	3%

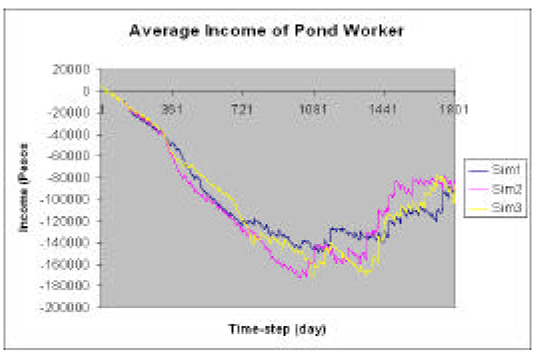
Appendix C: Results of the Verification of the Bohol Model

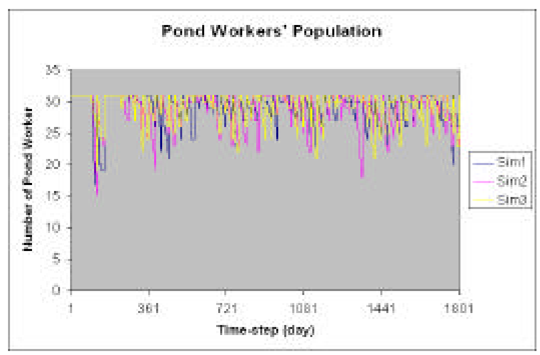


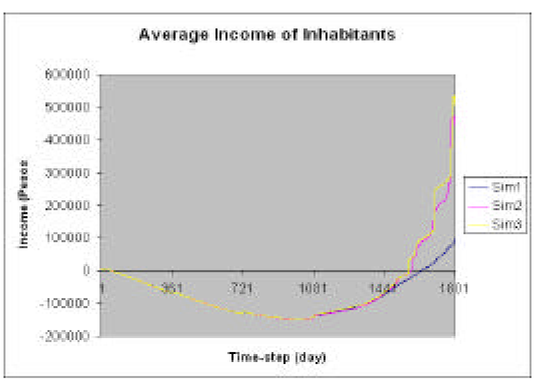


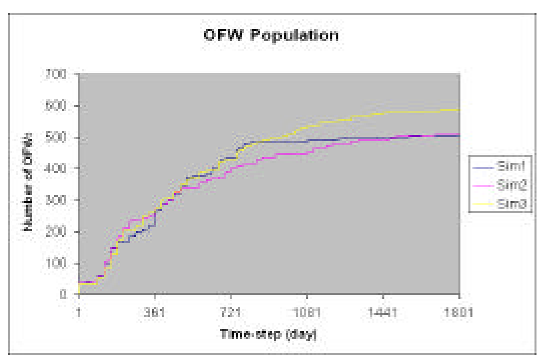


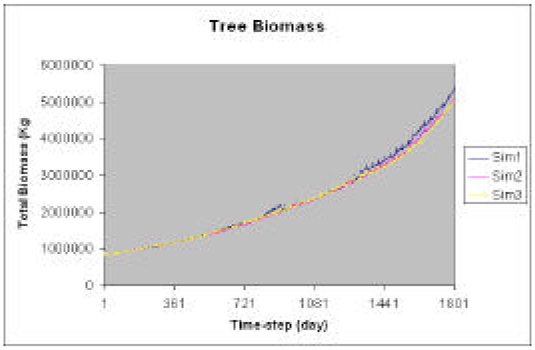


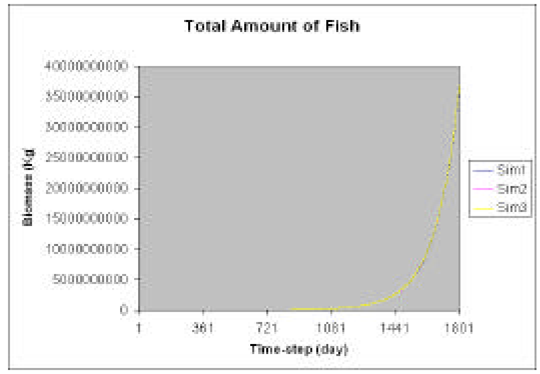


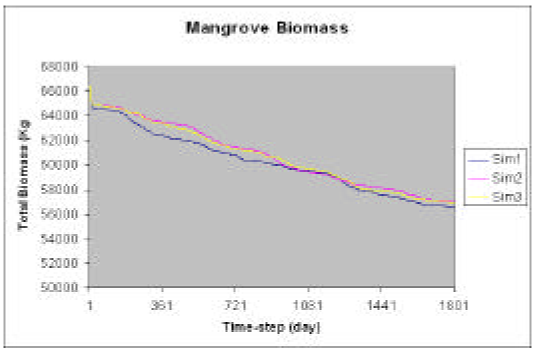


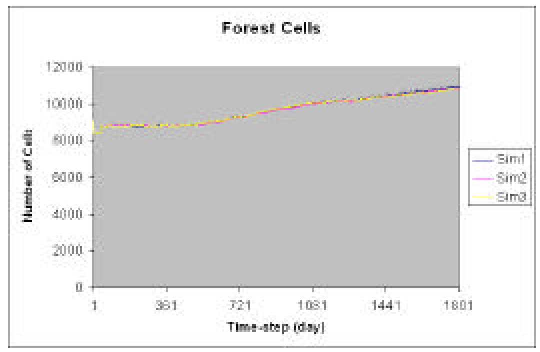


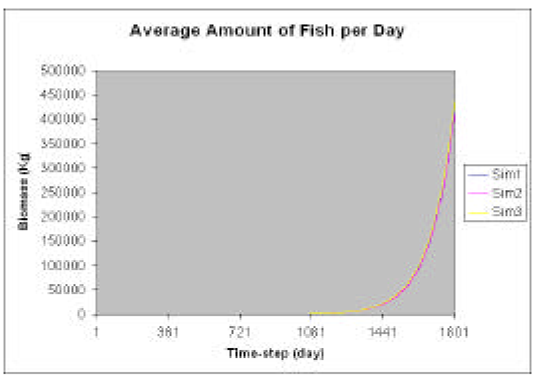


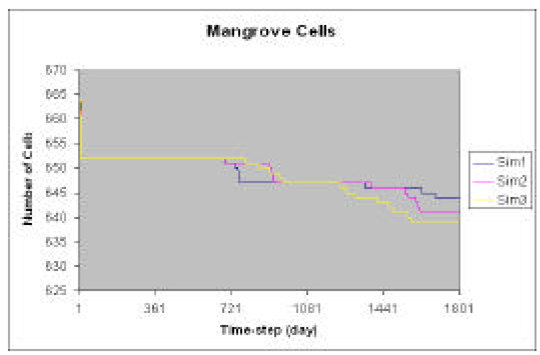

Tree Biomass
Total Biomass (Kg
Time-step (day)
Sim1
Sim2
Sim3


Total Amount of Fish
Biomass (Kg
Time-step (day)
Sim1
Sim2
Sim3


Mangrove Biomass
Total Biomass (Kg
Time-step (day)
Sim1
Sim2
Sim3


Forest Cells
Number of Cells
Time-step (day)
Sim1
Sim2
Sim3


Average Amount of Fish per Day
Biomass (Kg)
Time-step (day)
Sim1
Sim2
Sim3

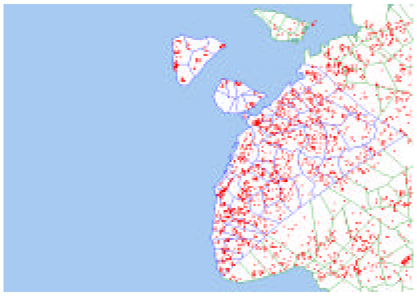

Mangrove Cells
Number of Cells
Time-step (day)
Sim1
Sim2
Sim3

Appendix D: Results of the Scenarios of the Bohol Model

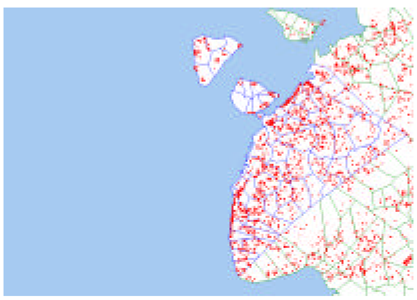
Change-Detection Maps

Legend

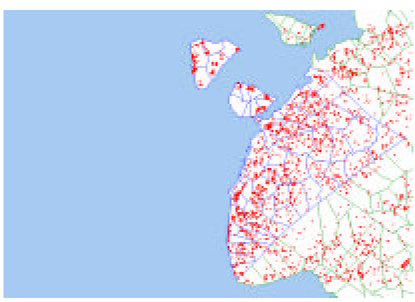
- Changed
- barangay w/in Loon
- barangay outside Loon



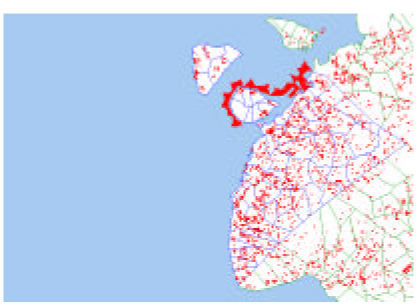
Scenario 1



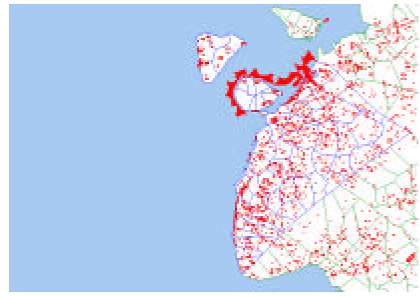
Scenario 2



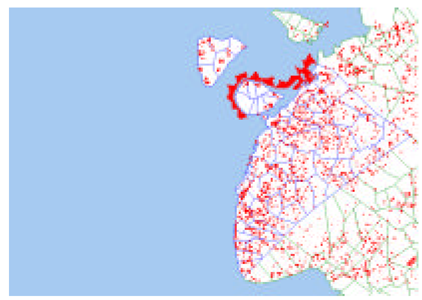
Scenario 3



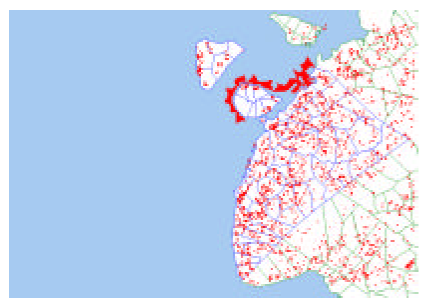
Scenario 4



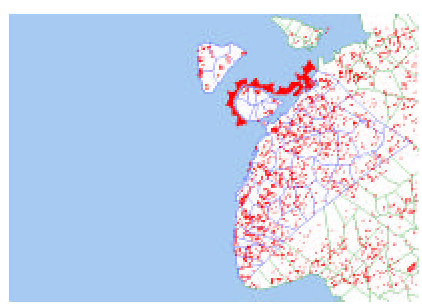
Scenario 5



Scenario 6



Scenario 7



Scenario 8

Cross Tabulations

Scenario 1

	Final State (Scenario 1)														
Initial State	Land Use / Cover	Beach	Flats	Sea grass	Coral	Mangrove	Water	Mud	Forest	Farm	Grassland	Bare	Fishpond	Built-up	Quarry	Total
	Beach	31	0	0	0	0	0	0	0	0	0	0	0	0	0	31
	Flats	0	172	0	0	0	0	0	0	0	0	0	0	0	0	172
	Sea grass	0	0	566	0	0	0	0	0	0	0	0	0	0	0	566
	Coral	0	0	0	537	0	0	0	0	0	0	0	0	0	0	537
	Mangrove	0	0	0	0	664	0	0	0	0	0	0	0	0	0	664
	Water	0	0	0	0	0	19804	0	0	0	0	0	0	0	0	19804
	Mud	0	0	0	0	0	0	209	0	0	0	0	0	0	0	209
	Forest	0	0	0	0	0	0	0	8975	77	0	9	0	0	0	9061
	Farm	0	0	0	0	0	0	0	0	2015	0	0	0	0	0	2015
	Grassland	0	0	0	0	0	0	0	0	0	4695	0	0	0	0	4695
	Bare Soil	0	0	0	0	0	0	0	1866	18	0	2357	0	0	0	4241
	Fishpond	0	0	0	0	0	0	0	0	0	0	0	55	0	0	55
	Built-up	0	0	0	0	0	0	0	0	0	0	0	0	56	0	56
	Quarry	0	0	0	0	0	0	0	0	0	0	0	0	0	6	6
	Total	31	172	566	537	664	19804	209	10841	2110	4695	2366	55	56	6	42112

Scenario 2

	Final State (Scenario 2)															
	Land Use / Cover	Beach	Flats	Sea grass	Coral	Mangrove	Water	Mud	Forest	Farm	Grassland	Bare	Fishpond	Built-up	Quarry	Total
Initial State	Beach	31	0	0	0	0	0	0	0	0	0	0	0	0	0	31
	Flats	0	172	0	0	0	0	0	0	0	0	0	0	0	0	172
	Sea grass	0	0	566	0	0	0	0	0	0	0	0	0	0	0	566
	Coral	0	0	0	537	0	0	0	0	0	0	0	0	0	0	537
	Mangrove	0	0	0	0	558	0	106	0	0	0	0	0	0	0	664
	Water	0	0	0	0	0	19804	0	0	0	0	0	0	0	0	19804
	Mud	0	0	0	0	0	0	209	0	0	0	0	0	0	0	209
	Forest	0	0	0	0	0	0	0	8994	64	0	3	0	0	0	9061
	Farm	0	0	0	0	0	0	0	0	2015	0	0	0	0	0	2015
	Grassland	0	0	0	0	0	0	0	0	0	4695	0	0	0	0	4695
	Bare Soil	0	0	0	0	0	0	0	1834	23	0	2384	0	0	0	4241
	Fishpond	0	0	0	0	0	0	0	0	0	0	0	55	0	0	55
	Built-up	0	0	0	0	0	0	0	0	0	0	0	0	56	0	56
	Quarry	0	0	0	0	0	0	0	0	0	0	0	0	0	6	6
	Total	31	172	566	537	558	19804	315	10828	2102	4695	2387	55	56	6	42112

Scenario 3

	Final State (Scenario 3)														
	Land Use / Cover	Beach	Flats	Sea grass	Coral	Mangrove	Water	Mud	Forest	Farm	Grassland	Bare	Fishpond	Built-up	Quarry	Total
Initial State	Beach	31	0	0	0	0	0	0	0	0	0	0	0	0	0	31
	Flats	0	172	0	0	0	0	0	0	0	0	0	0	0	0	172
	Sea grass	0	0	566	0	0	0	0	0	0	0	0	0	0	0	566
	Coral	0	0	0	537	0	0	0	0	0	0	0	0	0	0	537
	Mangrove	0	0	0	0	644	0	20	0	0	0	0	0	0	0	664
	Water	0	0	0	0	0	19804	0	0	0	0	0	0	0	0	19804
	Mud	0	0	0	0	0	0	209	0	0	0	0	0	0	0	209
	Forest	0	0	0	0	0	0	0	8995	63	0	3	0	0	0	9061
	Farm	0	0	0	0	0	0	0	0	2015	0	0	0	0	0	2015
	Grassland	0	0	0	0	0	0	0	0	0	4695	0	0	0	0	4695
	Bare Soil	0	0	0	0	0	0	0	1973	27	0	2241	0	0	0	4241
	Fishpond	0	0	0	0	0	0	0	0	0	0	0	55	0	0	55
	Built-up	0	0	0	0	0	0	0	0	0	0	0	0	56	0	56
	Quarry	0	0	0	0	0	0	0	0	0	0	0	0	0	6	6
	Total	31	172	566	537	644	19804	229	10968	2105	4695	2244	55	56	6	42112

Scenario 4

	Final State (Scenario 4)															
Initial State	Land Use / Cover	Beach	Flats	Sea grass	Coral	Mangrove	Water	Mud	Forest	Farm	Grassland	Bare	Fishpond	Built-up	Quarry	Total
	Beach	31	0	0	0	0	0	0	0	0	0	0	0	0	0	31
	Flats	0	172	0	0	0	0	0	0	0	0	0	0	0	0	172
	Sea grass / weed	0	0	566	0	0	0	0	0	0	0	0	0	0	0	566
	Coral	0	0	0	537	0	0	0	0	0	0	0	0	0	0	537
	Mangrove	0	0	0	0	664	0	0	0	0	0	0	0	0	0	664
	Water	0	0	0	0	438	19366	0	0	0	0	0	0	0	0	19804
	Mud	0	0	0	0	20	0	189	0	0	0	0	0	0	0	209
	Forest	0	0	0	0	0	0	0	8982	79	0	0	0	0	0	9061
	Farm	0	0	0	0	0	0	0	0	2015	0	0	0	0	0	2015
	Grassland	0	0	0	0	0	0	0	0	0	4695	0	0	0	0	4695
	Bare	0	0	0	0	0	0	0	1875	23	0	2343	0	0	0	4241
	Fishpond	0	0	0	0	0	0	0	0	0	0	0	55	0	0	55
	Built-up	0	0	0	0	0	0	0	0	0	0	0	0	56	0	56
	Quarry	0	0	0	0	0	0	0	0	0	0	0	0	0	6	6
	Total	31	172	566	537	1122	19366	189	10857	2117	4695	2343	55	56	6	42112

Scenario 5

	Final State (Scenario 5)															
	Land Use / Cover	Beach	Flats	Sea grass	Coral	Mangrove	Water	Mud	Forest	Farm	Grassland	Bare	Fishpond	Built-up	Quarry	Total
Initial State	Beach	31	0	0	0	0	0	0	0	0	0	0	0	0	0	31
	Flats	0	172	0	0	0	0	0	0	0	0	0	0	0	0	172
	Sea grass	0	0	566	0	0	0	0	0	0	0	0	0	0	0	566
	Coral	0	0	0	537	0	0	0	0	0	0	0	0	0	0	537
	Mangrove	0	0	0	0	552	0	112	0	0	0	0	0	0	0	664
	Water	0	0	0	0	441	19363	0	0	0	0	0	0	0	0	19804
	Mud	0	0	0	0	20	0	189	0	0	0	0	0	0	0	209
	Forest	0	0	0	0	0	0	0	8988	70	0	3	0	0	0	9061
	Farm	0	0	0	0	0	0	0	0	2015	0	0	0	0	0	2015
	Grassland	0	0	0	0	0	0	0	0	0	4695	0	0	0	0	4695
	Bare	0	0	0	0	0	0	0	1889	24	0	2328	0	0	0	4241
	Fishpond	0	0	0	0	0	0	0	0	0	0	0	55	0	0	55
	Built-up	0	0	0	0	0	0	0	0	0	0	0	0	56	0	56
	Quarry	0	0	0	0	0	0	0	0	0	0	0	0	0	6	6
	Total	31	172	566	537	1013	19363	301	10877	2109	4695	2331	55	56	6	42112

Scenario 6

	Final State (Scenario 6)														
Initial State	Land Use / Cover	Beach	Flats	Sea grass	Coral	Mangrove	Water	Mud	Forest	Farm	Grassland	Bare	Fishpond	Built-up	Quarry	Total
	Beach	31	0	0	0	0	0	0	0	0	0	0	0	0	0	31
	Flats	0	172	0	0	0	0	0	0	0	0	0	0	0	0	172
	Sea grass	0	0	566	0	0	0	0	0	0	0	0	0	0	0	566
	Coral	0	0	0	537	0	0	0	0	0	0	0	0	0	0	537
	Mangrove	0	0	0	0	643	0	21	0	0	0	0	0	0	0	664
	Water	0	0	0	0	437	19367	0	0	0	0	0	0	0	0	19804
	Mud	0	0	0	0	20	0	189	0	0	0	0	0	0	0	209
	Forest	0	0	0	0	0	0	0	8995	65	0	1	0	0	0	9061
	Farm	0	0	0	0	0	0	0	0	2015	0	0	0	0	0	2015
	Grassland	0	0	0	0	0	0	0	0	0	4695	0	0	0	0	4695
	Bare	0	0	0	0	0	0	0	1885	25	0	2331	0	0	0	4241
	Fishpond	0	0	0	0	0	0	0	0	0	0	0	55	0	0	55
	Built-up	0	0	0	0	0	0	0	0	0	0	0	0	56	0	56
	Quarry	0	0	0	0	0	0	0	0	0	0	0	0	0	6	6
	Total	31	172	566	537	1100	19367	210	10880	2105	4695	2332	55	56	6	42112

Scenario 7

	Final State (Scenario 7)														
	Land Use / Cover	Beach	Flats	Sea grass	Coral	Mangrove	Water	Mud	Forest	Farm	Grassland	Bare	Fishpond	Built-up	Quarry	Total
Initial State	Beach	31	0	0	0	0	0	0	0	0	0	0	0	0	0	31
	Flats	0	172	0	0	0	0	0	0	0	0	0	0	0	0	172
	Sea grass	0	0	566	0	0	0	0	0	0	0	0	0	0	0	566
	Coral	0	0	0	537	0	0	0	0	0	0	0	0	0	0	537
	Mangrove	0	0	0	0	664	0	0	0	0	0	0	0	0	0	664
	Water	0	0	0	0	438	19366	0	0	0	0	0	0	0	0	19804
	Mud	0	0	0	0	20	0	189	0	0	0	0	0	0	0	209
	Forest	0	0	0	0	0	0	0	8986	73	0	2	0	0	0	9061
	Farm	0	0	0	0	0	0	0	0	2015	0	0	0	0	0	2015
	Grassland	0	0	0	0	0	0	0	0	0	4695	0	0	0	0	4695
	Bare	0	0	0	0	0	0	0	1847	29	0	2365	0	0	0	4241
	Fishpond	0	0	0	0	0	0	0	0	0	0	0	55	0	0	55
	Built-up	0	0	0	0	0	0	0	0	0	0	0	0	56	0	56
	Quarry	0	0	0	0	0	0	0	0	0	0	0	0	0	6	6
	Total	31	172	566	537	1122	19366	189	10833	2117	4695	2367	55	56	6	42112

Scenario 8

	Final State (Scenario 8)														
	Land Use / Cover	Beach	Flats	Sea grass	Coral	Mangrove	Water	Mud	Forest	Farm	Grassland	Bare	Fishpond	Built-up	Quarry	Total
Initial State	Beach	31	0	0	0	0	0	0	0	0	0	0	0	0	0	31
	Flats	0	172	0	0	0	0	0	0	0	0	0	0	0	0	172
	Sea grass	0	0	566	0	0	0	0	0	0	0	0	0	0	0	566
	Coral	0	0	0	537	0	0	0	0	0	0	0	0	0	0	537
	Mangrove	0	0	0	0	643	0	21	0	0	0	0	0	0	0	664
	Water	0	0	0	0	442	19362	0	0	0	0	0	0	0	0	19804
	Mud	0	0	0	0	20	0	189	0	0	0	0	0	0	0	209
	Forest	0	0	0	0	0	0	0	8976	85	0	0	0	0	0	9061
	Farm	0	0	0	0	0	0	0	0	2015	0	0	0	0	0	2015
	Grassland	0	0	0	0	0	0	0	0	0	4695	0	0	0	0	4695
	Bare	0	0	0	0	0	0	0	1904	15	0	2322	0	0	0	4241
	Fishpond	0	0	0	0	0	0	0	0	0	0	0	55	0	0	55
	Built-up	0	0	0	0	0	0	0	0	0	0	0	0	56	0	56
	Quarry	0	0	0	0	0	0	0	0	0	0	0	0	0	6	6
	Total	31	172	566	537	1105	19362	210	10880	2115	4695	2322	55	56	6	42112