ECOSYSTEMS IN THE MIND: FUZZY COGNITIVE MAPS OF THE KIZILIRMAK DELTA WETLANDS IN TURKEY

Uygar Özesmi

Department of Environmental Engineering

Erciyes University, 38039 Kayseri, Turkey

uygar@ozesmi.org

Abstract

Sustainability of ecosystems and ecosystem management are increasingly accepted societal goals. However projects of non-governmental conservation organizations (NGOs) and governments also are prone to becoming impractical impositions on local people. Can conservation programs be improved by incorporating local people's understanding of ecosystems? The Kizilirmak Delta is one of Turkey's most important wetland complexes with its rich biodiversity and critical habitat for globally endangered bird species. It is also one of the most productive agricultural deltas in Turkey. We have drafted, together with stakeholders, 31 cognitive models of the social and ecological system. These models were converted to adjacency matrices, analyzed using graph theoretical methods, and augmented into social cognitive maps. Causal models were run based on neural network computational methods. "What-if" scenarios were run to determine the trajectory of the ecosystem based on the ecosystem models defined by stakeholders. Villagers had significantly larger numbers of variables, more complex maps, a broader understanding of all the variables that affect the Kizilirmak Delta, and mentioned more variables that control the ecosystem than did NGO and government officials. Villagers had developed a large capacity to adapt to changing ecological and social conditions. They actively changed and challenged these conditions through the political process. Villagers were faced with many important forcing functions that they could not control. Most of the variables defined by villagers were related to agriculture and animal husbandry. Conservation policies and ecosystem management must encompass larger environmental issues that villagers raise as much as biodiversity and villagers' cognitive maps must be reconciled with that of NGOs and government officials. Cognitive maps can serve as a basis for discussion when policies and management options are formulated. A villager-centered cognitive mapping approach is not only necessary because villagers resist conservation projects, or because top down projects that do not take local knowledge systems into account fail, but because it is the ethical and responsible way of doing ecosystem management.

Keywords: Conservation, Fuzzy Cognitive Maps, Cognitive Models, Artificial Intelligence, Wetlands, Sustainability, Ecosystem Management, Local Knowledge Systems, Villagers, NGO, Government.

INTRODUCTION

The Kizilirmak Delta is one of Turkey's most important wetland complexes with its rich biodiversity and critical habitat for globally endangered bird species. It is also one of the most productive agricultural deltas in Turkey. Because of these qualities, the delta has been declared a Ramsar Site, a wetland of international importance by the Ministry of Environment (Resmi-Gazete 1998). The Delta is located in the central Black Sea region of Turkey (41°30 to 41°45' N, 35°43' to 36°08' E), and covers an area of 50,000 ha that includes 15,000 ha of freshwater marshes and swamps, coastal lakes, and lagoons (Fig. 1). More than 310 bird species, or 75% of all known bird species in Turkey, use the delta for breeding, wintering, and migration. It hosts several globally threatened species including the Dalmatian Pelican (*Pelecanus crispus*), White-headed Duck (*Oxyura leucocephala*), Red-breasted Goose (Branta ruficollis), Ferruginous Duck (*Aythya nyroca*) and Imperial Eagle (*Aquila heliaca*) (Hustings and Dijk 1993). Limited studies report 10 species of mammals, 8 species of reptiles, 8 species of fish, and 18 species of invertebrates in the delta (Hustings and Dijk 1993; Ozesmi and Karul 1990).

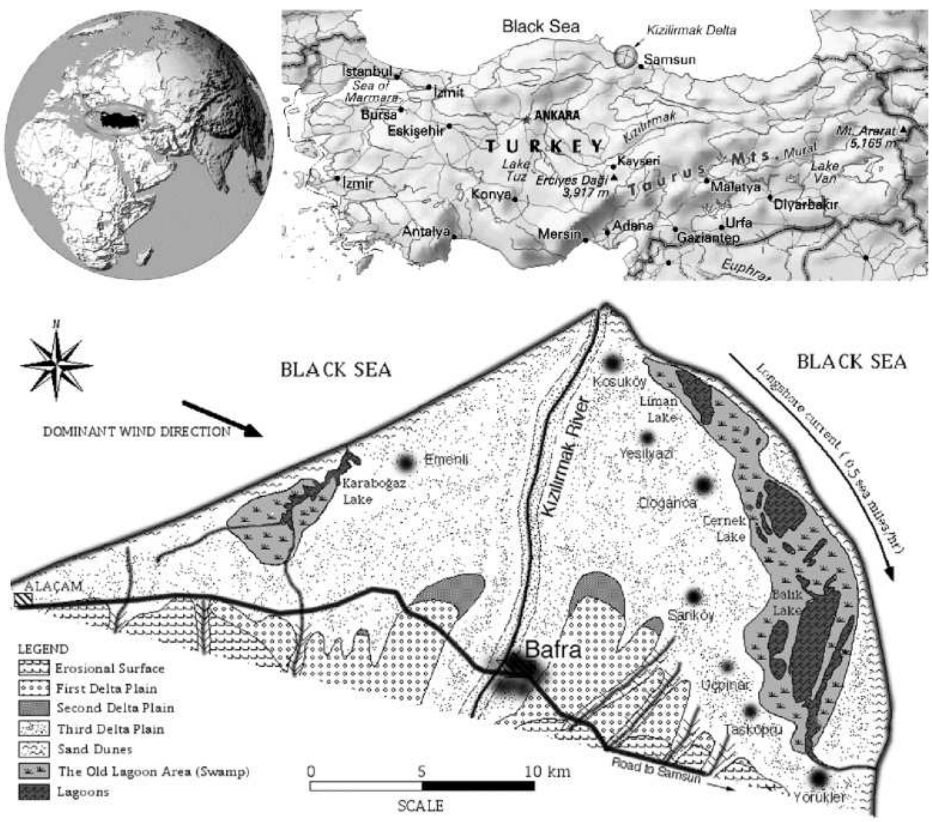


Figure 1: The location of the Kizilirmak Delta at the Black Sea coast of Turkey. The delta is constituted mainly of the third delta plain that has formed in the last 10,000 years. The shape and formation of lagoon barriers are controlled by sediment influx from the rivers and longshore currents (Akkan 1970; Ozesmi 1992). Behind lagoon barriers, 15,000 ha of wetland and lagoon habitat has formed.

Human populations have settled around wetland ecosystems since prehistory (Coles and Coles 1992). People have inhabited the Kizilirmak Delta at least since the Chalcolithic (Alkim et al. 1988) . They have used many products extracted from the wetlands including fish, waterfowl, thatch, commercial harvest of aquatic vegetation, hay, fodder, timber, and more recently rice agriculture and recreation (Alkim et al. 1999; Ozesmi, 2003; Tekkaya and Payne 1988). Today all of the first and second delta plains and most of the third delta plain is dominated by agriculture, crisscrossed by drainage and irrigation canals and roads. Settlements are dispersed with small village centers at crossroads typically including a mosque, school, health center, tea-house and grocery store.

It is not uncommon for a heated discussion to break out in the tea-houses or homes around the wetlands on the future of the Kizilirmak Delta and the livelihood of the villagers. A conflict exists over the future of the delta between the stakeholders; the villagers, vacation home owners, government entities and the NGOs. The Department of National Parks has wanted to declare the area a national park since the 1970s. After learning about the plans for a national park, a group of village elders visited the first bird sanctuary, Manyas Lake, a national park in western Turkey in 1985. The villagers around Manyas Lake told the delegates how their livelihood practices were disrupted by the park. When delegates reported to the village what they had been told, villagers reached a consensus opinion against the national park. The aversion to the park increased when wealthier villagers who were engaged in illegal real estate deals in ecologically sensitive areas came into conflict with NGOs that were working to conserve the Kizilirmak Delta ecosystem. As in many other ecologically sensitive areas an absolute protection strategy failed and conflict escalated among stakeholders.

But, there is also a consensus among stakeholders that the wetland ecosystem is rapidly degrading. Alternative strategies are urgently needed for the conservation of this unique ecosystem. Therefore, the implicit normative goal of this paper is the conservation of the Kizilirmak Delta. However, for this goal, I do not reason based on consequentialist ethics, but argue that any viable conservation strategy in the future has to involve different stakeholders and must integrate in the process local peoples concerns and understanding of ecosystem with that of government and NGO officials.

In this study I attempt to identify and reconcile the views of different the stakeholders on how the Kizilirmak Delta ecosystem functions. Stakeholders are encouraged to define the most important variables, and the cause and effect processes in the delta. Sustainable resource use for the conservation of the wetland ecosystem will not be adopted by the villagers if it does not originate from their own perceptions of the system. I use individual and social fuzzy cognitive maps of stakeholder groups to analyze the ways in which the perceptions of these groups are both different and similar. These different and shared knowledges are drawn upon to develop viable conservation strategies. I run simulations of different conservation strategies based on the social cognitive maps of the stakeholders to provide policy options.

The information obtained from this study should be valuable for developing policies and strategies to help ensure the sustainability of the Kizilirmak Delta wetland ecosystem as well as the livelihoods of the people living around them. The approach and results may provide insights to the conservation of similar ecosystems where a conflict exists among different stakeholders.

METHODS

Introduction to Fuzzy Cognitive Maps

Fuzzy cognitive maps have their roots in graph theory, first formulated by Euler in 1736 (Biggs et al. 1976). Since then graph theory has been developed extensively by mathematicians, but Harary et al. (1965) first presented the theory of directed graphs (digraphs) for investigators studying the structural properties of the empirical world. This empirical world in our case is the Kizilirmak Delta wetland ecosystem. Anthropologists have used signed digraphs to represent different social structures in human society (Hage and Harary 1983). Axelrod (1976) transferred signed digraphs from an empirical realm as understood by the anthropologist to the assertions of the informants. For this representation Axelrod (1976) coined the term cognitive map (first used by Tolman (1948)) that graphed causal relationships among variables as defined and described by people. Numerous studies have used cognitive mapping to look at decision making and conceptions of complex social systems (Axelrod 1976; Bauer 1975; Bougon et al. 1977; Brown 1992; Carley and Palmquist 1992; Cossette and Audet 1992; Hart 1977; Klein and Cooper 1982; Malone 1975; Montazemi and Conrath 1986; Nakamura et al. 1982; Rappaport 1979; Roberts 1973). These studies opened the way for using cognitive maps to represent local knowledge systems as told by informants. In this study the cognitive maps were the causal descriptions of the Kizilirmak Delta Ecosystem as drawn by villagers, NGO and government officials. The main assumption of this approach is that individuals have cognitive models that are internal representations of a partially observed world (Bauer 1975). This assumption has been verified quite extensively by the works of cognitive psychologists (Anderson 1983), and physiologists, anthropologists and sociologist have studied how humans construct these cognitive maps (Bateson 1972; Bateson 1979; Hannigan 1995; Jerison 1973). There have been many studies that have used a cognitive mapping approach. Klein and Cooper (1982, p. 64). succinctly summarize the new perspective that this type of research offers: "Traditionally, scientists ... have been concerned with the real, objective world, where phenomena can be observed and measured. However, human decision processes never take place in this objective world ... Human decision processes always take place within the subjective world of the individual decision-maker. Cognitive mapping offers a window on this subjective world."

Fieldwork

As a starting point before going out into the field, I constructed my own cognitive map of the Kizilirmak Delta ecosystem giving real numbers to edges (causal connections) in the interval [-1,1]. In doing so I introspectively questioned my own assumptions and understanding of the ecosystem as they had evolved since I first visited the delta in 1989. This enabled me to be aware of my model and not be unconsciously influenced by it, when I was drawing cognitive maps with the informants. I recommend this exercise to be done before going to the field to any future research on cognitive mapping.

In the summers of 1997 and 1998, I spent a total of six months in Turkey doing research for developing sustainable resource use strategies for the Kizilirmak Delta. I lived in villages and fishing huts located around the wetlands of the Kizilirmak Delta. I interviewed villagers in their spare time, as well as local NGO and government officials in Bafra and Samsun and central NGO and government officials in Istanbul and Ankara. I conducted in-depth interviews (Denzin and Lincoln 1994) and drew cognitive maps with villagers and officials (Appendix I). The structure of the interviews was based on model primitives (concepts and statements) and used the first two steps of textual analysis for drawing cognitive maps as described by Carley and Palmquist (1992). The interview started by asking an open-ended question: "What are the most important variables (concepts) in the Kizilirmak Delta". If I was asked to further clarify the question I said: "Variables that make the Kizilirmak Delta, variables related to your experiences, livelihood and the sustainable development of the delta, plain, which ever is relevant to you." After the informant listed all variables and had nothing more to add, the variables were put on a sheet of paper as circled units and the connections (edges, statements) among variables were explored with informants (Appendix I). The interviewing method I used is more direct than textual analysis, coding from a printed text, and allows for cognitive maps directly drawn on paper by the interviewees . The informants drew lines with arrows and +/- signs from variables they selected to another variable showing causal decrease or increase. They were asked to give the strength of the causal relationship as a real number in [-1,1] or say whether it was strong, medium, or low. The informants were encouraged to add variables to their initial list as they seemed appropriate at this stage. The informant was invited to describe and clarify stated relationships and notes were taken. Interviews lasted an average of one and a half hours in the range of 45 minutes to four hours. Each interview was terminated when informants were satisfied with their cognitive map and had nothing more to add. In this study I found cognitive mapping to be especially useful because of a previous aversion to questionnaire techniques encountered in the region. The openness and transparency of cognitive maps makes them ethically more defensible compared to other methods. I also preferred cognitive mapping because active drawing with informants facilitates a broader and holistic discussion on the delta ecosystem, conservation and livelihood practices providing insights to reasoning, beliefs, and values. Brown (1992) presents further pro et contra aspects of cognitive mapping technique compared to other potential methods.

The final product was a cognitive map with the most important variables and the causal relationships that were perceived between these variables for each informant. A total of 31 cognitive maps were used in the analysis. Of these 31 maps, 15 were drawn by inhabitants of the Kizilirmak Delta coming from 5 villages, 2 were drawn by vacation home owners, 7 were drawn by local and national NGO officials, 7 were from government officials. Of the 7 cognitive maps from government officials, 3 were drawn during the interview and 4 were extracted from the conversational interview text by coding, based on the concepts that they have stated at the start of the interview (Carley and Palmquist 1992; Wrightson 1976).

Neural Network Computation

The cognitive maps were then transformed according to graph theory into adjacency matrices in the form $A(D) = [a_{ij}]$ (Harary et al. 1965) where the variables ν_i (e.g. pollution) were listed on the vertical axis and ν_j (e.g. fish population) on the horizontal axis forming a square matrix. Matrix entries were made based on the cognitive map. For example -1 was entered for a_{ij} if there was a causal decrease from ν_i to ν_j (eg. pollution decreased fish populations) (Fig. 2). The adjacency matrices of the cognitive maps where then treated as Fuzzy Cognitive Maps (FCM).

	1.	2.	3.	4.
1. Amount of Wetland	0	1.0	-0.1	0.8
2. Fish Population	0	0	0	1.0
3. Pollution	-0.2	-1.0	0	-0.2
4. Livelihood	0	0	0	0

Figure 2: A simplified illustration of an adjacency matrix, where pollution (ν_3) causes a decrease of -1 (a_{32}) in fish population (ν_2).

FCMs are useful in symbolic representations of semantic networks and they also provide a method for modelling cognitive and empirical cause-effect processes. Their advantage lies in that they allow feedback processes (Kosko 1992b). Anyone can freely draw causal pictures of problems or systems of any kind. For example, Taber (1991; 1987) used FCMs to model physiology of food appetite and political developments. Styblinski and Meyer (1988) used them to analyze electrical circuits. Gotoh and Murakami (1989 as cited in Kosko 1992) used FCMs to model industrial plant control. Dickerson and Kosko (1994) used them to model marine food web interactions. Craiger et al. (1996) used them to simulate organizational behavior and job satisfaction. Radomski and Goeman (1996) used FCM to suggest ways to improve decision making in sport-fisheries management. Schneider et al. (1998) used United Nations data on 106 countries to automatically build an economic/demographic model of world nations from statistical data.

Kosko (1986) coined the term FCM when he modified Axelrod's cognitive maps by applying fuzzy causal functions with real numbers in [-1, 1] to connections (also called lines, edges, synapses). Auto-associative neural network architecture (Reimann 1998) is the basis of FCM. Neural networks (also called connectionist architectures and parallel distributed processing systems) are groups of simple, highly interconnected processing units which act together to perform computable functions (Fig. 3). FCMs allow 'causal inferences to be made as feedback associative memory recollections' (Kosko 1987). The inference was accomplished in the cognitive maps representing the Kizilirmak Delta Ecosystem by a neural network computational method in which a vector of initial states of variables (I^n) was multiplied with the adjacency matrix A of the cognitive map. The matrix values are of variable strength, that are represented by real numbers. The lines carry the input from one variable (what is called a point, node, or unit) to another activating the unit. The contribution of one connection to the unit is the product of the activity on the line and the value of the connection strength. The total input to the unit is the sum of all the individual products (Fig. 3).

Lines can be positive or negative. Positive connections add to the activity total, while negative connections subtract from it. The output of the unit is a function of the total input. In this inference method usually a threshold function or a transformation by a bounded monotonic increasing function is applied to the result of the matrix multiplication, $I^n \times A$, at each simulation time step (Kosko 1987; Kosko 1992b). Commonly used activation functions are logistic, linear threshold or step functions. I used a logistic function $1/(1+e^{-X})$to transform the results into the interval [0,1]. This non-negative transformation allows for a better understanding and representation of activation levels of variables and enables a qualitative comparison among the causal output of variables. The resulting transformed vector then was signaled through the adjacency matrix and transformed repeatedly until the system converged to a fixed point in less than 30 simulation time steps. Theoretically it could have also settled into a limit cycle, or chaotic attractor (Dickerson and Kosko 1994).

Using this neural network computational method it is possible to run 'what-if' scenarios using the initial state vector. Specific variables related to a scenario can be 'clamped' in the vector by setting these variables at a desired value at each simulation step (Kosko 1988). The final result indicates where the system would end up given initial variable states or simulated policy options.

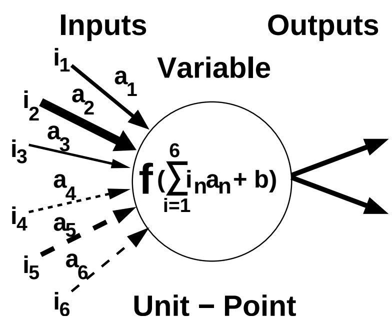


Figure 3: A simulated unit representing a variable in the cognitive ecosystem model. Black arrows represent positive signed and gray ones negative signed connections. All inputs are multiplied by weights of connections and then summed. The summation is input into a monotonic increasing function. The result is then output to other connected units.

Social Cognitive Maps

Laszlo et al. (1996) state that a set of cognitive maps of individuals form a social cognitive map that behaves differently than a simple addition or overlay of individual cognitive maps. Once a social cognitive map forms it takes a life on its own through social processes, recursively affecting individuals who act not only based on their own cognitive maps but are affected by the social cognitive maps. As Eden (1988, p.7) states: "An aggregated model constructed by combining each of the individual cognitive maps produces a "team map" that is no longer a representation of the cognition /thinking of anyone and does not belong to anyone." Social knowledge is defined as shared knowledge (Carley 1988) and is usually assumed to be obvious and may not be stated in cognitive maps readily. Therefore, the interviewer must have at least a rudimentary awareness of the study groups assumptions and beliefs and ask appropriate questions to elicit such social knowledge.

Based on Laszlo et al. (1996), I additively superimposed individual cognitive maps of informants that resulted in fuzzy cognitive maps (Kosko 1987; Kosko 1992a; Kosko 1992b) to form a social cognitive map. The resulting augmented social cognitive map shows different properties and results then an addition of the neural network computation results of individual cognitive maps. In the augmentation, while conflicting connections with opposite signs cancelled each other out, agreement reinforced causal relationships, forming a consensus social cognitive map based on equal representation. Zhang and Chen (1988) point out that the differing directions might be a result of different logical structure and suggest the use of a negative- positive-neutral calculus to compute compound values for augmented maps. In my study, the augmentation of maps was based on the equivalence properties of fuzzy causal relationships (FCR) among variables (Kim and Lee 1998). In augmented cognitive maps informant contributions can be scaled either by multiplying their adjacency matrix by a subjective weight or by assigning weights based on the degree of concurrence (Taber 1991; Taber and Siegel 1987). Schneider et al. (1998) point that weights based on concurrence might represent conservative maps at the expense of people thinking differently. Therefore, in this study an egalitarian assumption was made that all individual maps were equally valid and a weight of one has been assigned to each individual cognitive map. The social cognitive maps in this study represent only one point in time. One has to consider that a social cognitive map is not static in time and evolves as the community itself transforms. As Carley (1997) points out social cognitive maps are "lossy consensus" that dynamically change over time loosing parts by members leaving a community and others joining in. Community members might not have developed a shared language during their time together. Although they might have overlapping common beliefs about certain aspects of the systems, the partial shared beliefs do not guarantee that they can draw a social cognitive map together through a structured protocol. Power within group members can create an unequal environment of expression and sometimes conflict when drawing cognitive maps (Langfield-Smith 1992). Malone (1975) in a group exercise with eight students could also not come to a consensus and had to resort to voting in determining map connections. Drawing social cognitive maps in groups was not attempted in this study and all participants had equal representation in the final social cognitive maps.

Informants may draw cognitive maps that emphasize different parts of a system based on their experiences. This need not imply that these maps are wrong or less representative. To the contrary, the addition of these cognitive maps might yield a better representation of the system (Eden et al. 1979). Roberts (1973) states that the larger groups of experts yield more accurate and reliable information, and Nakamura et al. (1982) found that joining of cognitive maps generated useful information that was not captured by individual maps. In statistical terms, large numbers of independent and identically distributed (i.i.d.) observations will tend to produce stable edge values (Kosko 1988), and exponentially diminishing number of new variables. The slow accumulation of variables might be due to a limited vocabulary informants have with regards to the subject of inquiry. Carley and Palmquist (1992) report that 29 undergraduates mentioned up to 244 concepts on research writing and 45 students produced 217 concepts on tutor selection. One individual could only consider between 30 and 40 concepts in a session lasting between 20-40 minutes because of combinatorial explosion. Nakamura et al. (1982) obtained 152 concepts and 265 connections from 5 documents on traffic problems in Japan. Since people have shared concepts as the number of concepts increase the rate of increase in total number of concepts will quickly approach zero. The i.i.d. assumption is reasonable since the stakeholder groups are represented by separate individuals and they focus on the subject that is only the Kizilirmak Delta, so the domain focus corresponds to identical distribution (Kosko 1987; Kosko 1988; Taber and Siegel 1987).

Analyzing Cognitive Maps

Cognitive models are complex systems because they are made of a large number of units that have many interconnections. This structure results in an over all behavior of the system that is different than the sum of units. Therefore, the analysis of complex cognitive maps is difficult. There are no established statistical methods except for comparing concept and statement numbers in discrete or continuous categories with standard statistical techniques (Palmquist et al. 1997). The greater number of variables (N) in a cognitive map, the more complex the map is. However, matrix algebra tools of graph theory provide us with many more indices besides number of variables (concepts, statements) and their intersections. Comparing number of variables and indices of cognitive maps across different subject areas and interviewers might not be correct, because cognitive maps are dependent on the length of text or duration of interview and the skill of the interviewer (Eden et al. 1992). But comparisons by standard statistical tests among stakeholder maps on the same subject area elicited by the same interviewer as in the case of the Kizilirmak Delta is appropriate. In this study, Student's t-test was used for comparisons among indices. If samples were rejected to be normal based on Shapiro-Wilk and Kolmogorov-Smirnov Tests of Normality, non-parametric Mann-Whitney test was used instead of t-test.

Graph theory methods help analyzing the structural properties of cognitive maps, yet another way of analyzing cognitive maps is to use the above described computational neural network method. The computational method is a black-box modeling approach which is not necessarily concerned about the structure, but the outcome of the map. The results of the cognitive map simulation runs can then be compared, given a fixed structure of network because "the dynamics of the entire network must respect this structure" (Reimann 1998).

Another way of analyzing the structure of cognitive maps is to look how connected or sparse the maps are. There is information contained in the defined variables as well as the connections between them. The *density* of a cognitive map (D) is an index of connectivity:

$$D = \frac{C}{N(N-1)} \text{ or alternatively, } D = \frac{C}{N^2}$$

In the *density* equation C, the number of connections, is divided by the maximum number of connections possible between N variables (Hage and Harary 1983); if variables can have a causal effect on themselves then maximum number of connections is N^2.

The structure of a cognitive map apart from number of variables and connections can best be analyzed by finding *transmitter variables* (forcing functions, givens, tails), *receiver variables* (utility variables, ends, heads) and *immediate domains* (Bougon et al. 1977; Eden et al. 1992; Harary et al. 1965). These variables are defined by their *outdegree* [$od(v_i)$] and *indegree* [$id(v_i)$]. Outdegree is the row sum of absolute values of a variable in the adjacency matrix and shows the cumulative strengths of connections (a_{ij}) exiting the variable:

$$od(v_i) = \sum_{k-1}^{N} \bar{a_{ik}}$$

Indegree is the column sum of absolute values of a variable and shows the cumulative strength of variables entering the unit.

$$id(v_i) = \sum_{k-1}^{N} \bar{a_{ki}}$$

The immediate domain of a variable is the summation of its indegree (in-arrows) and outdegree (out-arrows) also called centrality. The contribution of a variable in a cognitive map can be understood by calculating its *centrality* (c) whether it is a transmitter, receiver or ordinary variable. The centrality (c) of a variable is also called its total degree [$td(v_i)$] (Harary et al. 1965):

$$c_i = td(v_i) = od(v_i) + id(v_i)$$

In fuzzy cognitive maps, in contrast to binary cognitive maps, a variable can be more central although it has less connections if the connections carry larger weights (Kosko 1986).

Transmitter variables are units whose $od(v_i)$ is positive and their $id(v_i)$ is 0. Receiver variables are units whose $od(v_i)$ is 0 and their $id(v_i)$ is positive. Other variables which have both non-zero $od(v_i)$ and $id(v_i)$ are ordinary variables (means) (Bougon et al. 1977).

The total number of receiver variables in a cognitive map can be considered an index of its complexity. Larger number of receiver variables indicate that the cognitive map considers many outcomes and implications that are a result of the system (Eden et al. 1992). On the other hand many transmitter variables indicate thinking with top down influences, a "formal hierarchical" system (Simon 1996) p. 185). Many transmitter units shows the "flatness" of a cognitive map where causal arguments are not well elaborated (Eden et al. 1992). Then we can compare cognitive maps in terms of their complexity by number of *receiver to transmitter variable ratios* (R/T). Larger ratios will indicate more complex maps, because they define more utility outcomes and less controlling forcing functions.

Another structural measure of a cognitive maps is the *hierarchy index* (h) (MacDonald 1983):

$$h = \frac{12}{(N-1)N(N+1)} \sum_i [od(v_i) - (\sum od(v_i))/N]^2$$

Where N is the total number of variables. When h is equal to one then the map is fully hierarchical and when h is equal to zero the system is fully democratic. In a similar schematic Sandel (1996) calls these domination (hierarchical) and adaptation eco-strategies (democratic) pointing that democratic maps are much more adaptable to the local environmental changes because of their high level of integration and dependence.

Model Abstraction: Simplifying Cognitive Maps by Condensation

The methods of analysis presented so far have all dealt with characterizing the whole map with an index for comparison or the contribution of one variable (centrality) to the map. Although these help us find important variables and compare different maps using indices, it does not contribute to a holistic understanding of how the map operates. Making sense of complex maps is difficult and twenty to thirty variables start being counterproductive for gaining insights. About a dozen variables seems to be typical in analysis (Buede and Ferrell 1993). The best way of approaching an understanding of complex maps is to simplify them.

How would one go about simplifying a map? According to graph theory an effective way to better understand the structure of complex cognitive maps is condensing them. Condensation is achieved by replacing subgraphs (consisting of a group of variables connected with lines) with a single unit (Harary et al. 1965). The connections of variables within subgraphs with other subgraphs are maintained when replacing groups of variables. The grouping and replacement is also called *aggregation*. The second question is then how do we decide on subgraphs?

There are two ways of deciding on subgraphs, *qualitative aggregation* and *quantitative aggregation*. In qualitative aggregation variables can be combined by categories that are represented by a larger encompassing variable. Hence Nakamura (Nakamura et al. 1982) condensed 152 variables coded from 5 documents into 16 categories. Similarly, in this study I combined 136 categories into 12 overarching variables based on the categories that have emerged after the listing. These categories emerge from themes that have been stated by the informants but also from their relevance to larger theoretical frameworks of current day scholarship, such as adaptive ecosystem management, community wildlife management, hydrogeomorphic controls, sustainable livelihoods and agriculture, ecological economics and common property resource management. The second way of condensing is quantitative aggregation. In this case one draws the graphical representation of the cognitive map and visually defines the strong components (re-enforcing cycles) as subgraphs (Harary et al. 1965). This approach is similar to the concept of near-decomposability (Iwasaki and Simon 1994). If we rearrange the adjacency matrix A so that the sub-adjacency matrices S_n of subgraphs align along the diagonal in the form,

$$A = \begin{vmatrix} S_1 & & & \epsilon \\ & S_2 & & \\ & & \ddots & \\ \epsilon & & & S_N \end{vmatrix}$$

and all elements outside the submatrices are zero, then the matrix is considered *completely decomposable*. However if some small number outside the subgraph is not equal to zero ($\epsilon \neq 0$) then the matrix is nearly decomposable. In a nearly decomposable system variables within a subsystem interact strongly, but their interaction to other variables of subsystems is weak. In nearly decomposable systems, variables in each subsystem move towards a relative equilibrium in the short-run and the system will run into an over-all equilibrium, maintaining relative equilibrium in each subsystem on the long-run. Naturally, the condensed cognitive map based on near-decomposability will approximate the full map better if ϵ is smaller (Iwasaki and Simon 1994). The assumption of near decomposability is valid in general, because in social and ecological systems it is rare that every variable is connected to every other variable with equal strength (Simon 1996).

So how would one decide on submatrices and arrange them along the diagonal? Cluster analysis can be used to decide on variables that make up subsystems in a cognitive map. Clustering enables us to find subsystems that have variables strongly interconnected with each other and have weak inter-group or variable links (Cossette and Audet 1992; Eden 1988). Most clustering analysis techniques are not overlapping (non-inclusive). However in inclusive clustering, recurring variables in clusters are important because of their ramifications in several different clusters (Eden et al. 1992). These recurring variables play central roles in cognitive maps. Cognitive maps that can be readily clustered or are nearly decomposable are thought to be more simple compared to ones where clustering is not as easy (Eden et al. 1992). The hierarchical and k-means clustering of the Kizilirmak Delta social cognitive maps resulted in one big cluster and several small ones. The clusters did not correspond to readily recognizable categories. This shows that the social cognitive maps of the stakeholder groups are very complex. On the other hand clustering shows hierarchy, and hierarchy is a property of complex systems (Simon 1996). The issue of hierarchy was approached with the previously described hierarchy index, and the failure to detect a meaningful clustering indicates that the social cognitive maps have little structural complexity based on Simon's concept of hierarchy. If clusters were achieved they would have pointed to a hierarchical or stratified system of layers, functional subsystems, or just divisions depending on the modelers intentions. We achieve this understanding by the the qualitative aggregation method described before.

Once the aggregation has been done, the new simplified system can be represented as a weighted digraph. While drawing the digraph, the cognitive map connections were drawn so that they reflect the weight and sign of the causal relationship. I call this representation cognitive interpretation diagram (CID) similar to the previously developed neural interpretation diagram (NID) (Ozesmi and Ozesmi 1999).

RESULTS AND DISCUSSION

The Content and Structure of Individual Cognitive Maps

The first step in analyzing cognitive maps is to describe and tabulate the variables, connections and the structural indices. The description and the tables can then be used to compare different stakeholder groups. In the 31 cognitive maps I analyzed on the Kizilirmak Delta, the average number of variables was 19$\pm$7 SD in the range of 9-34 variables. The average transmitter variables were 7.0$\pm$4.3 SD, average receiver variables were 3.0$\pm$2.4 SD, average ordinary variables were 8.9$\pm$3.3 SD per cognitive map. The maps had on average 28.3$\pm$10.6 SD connections that resulted in a density of 0.112$\pm$0.109 SD. The hierarchy indices were on average 0.082$\pm$0.135 SD. In a study of a small business environment, 57 concepts and 87 links were mentioned by the owner (Cossette and Audet 1992) which results in a connection to variable ratio of 1.53 and a density of 0.027. A study with a modal average of 75 minutes of interviewing of 116 informants elicited 32 concepts in the range from 14-59 (Brown 1992). Eden et al. (1992) found typical 1.15-1.20 ratios of links to nodes. I found 1.64$\pm$0.95 SD ratio of connections to variables which is comparable to the above mentioned studies.

The goal of this study is to compare cognitive maps of stakeholder groups and see how similar and different they are, and then find the differences and similarities both in structure and functioning in order to develop strategies that will enable stakeholders to strive for the conservation of the Kizilirmak Delta. At the start I made pair wise comparison to understand the association of cognitive maps of the stakeholders based on which variables they include (Table 1).

The comparison of the cognitive maps of stakeholders reveals that stakeholder groups are all significantly different from each other with the exception of NGO officials and government officials (Table 1). The low phi value and high Yule Q coefficient also indicates that NGO and government officials are the most similar among stakeholder groups. There was no significant difference among number of variables in NGO and Government officials cognitive maps (t-test, p=0.346), but the power of analysis was only 0.2. The results from McNemar test, Phi and Yule-Q coefficients supported by t-test prompted me to decide a priori to pool NGO and Government officials data, and only conduct statistical tests between villagers and pooled NGO and Government Officials (Table 1 and 2). Pooling NGO and government data is further justified by intensive communication between NGO and government officials and because they were referencing each other during interviews. Similarly Carley (1986) concludes that the degree of cognitive consensus is greater in tight social structures with high internal interaction.

Table 1: The comparison of similarity and dissimilarity in pairs between cognitive maps of the stakeholders.

	McNemar Test	Phi value	Yule Q
Villager - Vacation H. Owner	84.375	0.038	0.146789
Villager-NGO Officer	29.762	-0.186	-0.432704
Villager-Government Officer	22.413	-0.117	-0.283854
Villager-NGO&Government	7.579	**-0.326	***-0.836158
NGO-Vacation H. Owner	29.630	0.146	0.407207
NGO-Government Officer	*1.884	**0.370	***0.656566
NGO-NGO&Government	26.000	0.678	1.000000
Gov.-Vacation H. Owner	40.695	0.179	0.509982
Gov.-NGO&Government	17.000	0.775	1.000000
NGO&Government-Vacation	60.500	0.173	0.560510

* The McNemar Symmetry Chi-Square Test for association among matched pairs on shared variables shows that all stakeholder groups are significantly different except between NGO and Government officials.
** The phi value indicate the degree of similarity, where 1 is most similar. According to phi values the most similar cognitive maps are those of government and NGO officials maps and the most dissimilar ones are that of villagers compared to government and NGO officials.
*** Yule Q Coefficient is the proportionate reduction in errors in predicting whether or not one group has the variable based on the knowledge that the other group has that variable. The Yule Q value corroborates the results from Phi values.

The most different stakeholders are Villagers and NGO and government officials both in terms of phi values and Yule Q coefficient (Table 1). The villagers form the stakeholder group that is most impacted by any NGO or government project. The significant difference observed in cognitive maps between villagers and NGO and government officials separately and pooled indicates that before any project is implemented there is an important need to base these projects on the understanding of the villagers (Table 1). The villager-centered approach will avoid top down imposed projects. A villager-centered approach is not only necessary because top down projects that do not take into account local knowledge systems usually fail but because it is the ethical and responsible way of doing projects.

Villagers in the Kizilirmak Delta had an average of 22.0 variables, which is significantly more than the pooled NGO and Government Officials' 16.8 average variables (Table 2). The lower number of variables in NGO and government officials cognitive map compared to villagers does not necessarily mean that their understanding of the system is less competent than villagers. Klein and Cooper found that the quality of decision making was not correlated with the number of variables (Klein and Cooper 1982). The comparison of number of variables indicate that villagers have more complex maps than NGO and government officials, because they have significantly larger number of variables. However looking at the receiver to transmitter ratio, a better indicator of structure, we cannot say that they are structurally complex. Transmitter variables (higher in villagers) indicate a system that is controlled by forcing functions, a system that is controlled by a formal hierarchy, not a complex system with embedded *structural hierarchies*. NGO and government officials maps are also significantly denser with a larger hierarchy index, which is an indication of structural complexity (Table 2).

The comparison of indices point that villagers have a broader understanding of all the variables that affect the

Table 2: The average number of different variable types and indices for stakeholder groups in the Kizilirmak Delta.

	Villagers	Vacation H. Owners	NGO Officials	Government Officials	NGO & Govern. Officials
Number of Cognitive Maps	15	2	7	7	14
Number of Variables Mean $\pm$ SD	$^{A}21.9 \pm 7.0$	12.0 ± 1.4	15.1 ± 6.2	18.4 ± 6.3	$^{A}16.8 \pm 6.3$
Number of transmitter Variables	$^{B}9.3 \pm 3.8$	5.0 ± 0.0	3.6 ± 3.1	6.0 ± 4.5	$^{B}4.8 \pm 3.9$
Number of Receiver Variables	3.1 ± 2.3	2.5 ± 0.7	2.3 ± 2.4	3.7 ± 3.0	3 ± 2.7
Receiver/Transmitter Variable	$^{C}0.368 \pm 0.313$	0.500 ± 0.141	0.815 ± 0.732	0.532 ± 0.598	$^{C}0.830 \pm 0.688$
Number of Ordinary Variables	9.5 ± 3.6	4.5 ± 0.7	9.3 ± 1.9	8.7 ± 3.8	9 ± 2.9
Number of Connections	28.1 ± 9.8	14.5 ± 5.0	28.9 ± 9.5	32.0 ± 12.9	30.4 ± 11.0
Connection/Variable	$^{D}1.3 \pm 0.2$	1.2 ± 0.3	2.1 ± 1.1	2.1 ± 1.5	$^{D}2.1 \pm 1.3$
Density	$^{E}0.065 \pm 0.028$	0.099 ± 0.011	0.177 ± 0.141	0.151 ± 0.160	$^{E}0.164 \pm 0.146$
Hierarchy	$^{F}0.029 \pm 0.027$	0.075 ± 0.027	0.149 ± 0.130	0.131 ± 0.241	$^{F}0.140 \pm 0.186$

^{A}Number of variables significantly higher in villagers than government and NGO officials together (one-tailed t-test p=0.023).
^{B}Number of transmitter variables significantly higher in villagers than government and NGO officials together (one-tailed t-test p=0.002).
^{C}Complexity significantly higher in government and NGO officials together than villagers (one-tailed t-test p=0.039).
^{D}Connection to variable ratio significantly higher in government and NGO officials together than villagers (one-tailed Mann-Whitney test p=0.025).
^{E}Government and NGO officials maps are significantly denser than that of villagers (one-tailed Mann-Whitney test p= 0.015).
^{F}Government and NGO officials cognitive maps are significantly more hierarchical compared to villagers (one-tailed Mann-Whitney test p= 0.004).

Kizilirmak Delta and mention more variables that control the ecosystem than NGO and Government Officials. Although there was no significant difference among stakeholder groups in terms of receiver and ordinary variables, villagers have a higher number of transmitter variables (Table 2). Larger amount of transmitters result in a map that has a *formal hierarchy*, yet their cognitive maps are *structurally democratic*, which indicates that they developed a larger capacity to adapt to changing conditions. NGO and government officials see fewer variables presumably because they do not live and earn their living on a daily basis in the delta. Structurally, they see highly interrelated variables that are strongly affecting each other and affecting other variables less, forming *structurally hierarchical* cognitive maps.

This analysis indicates that villagers are faced with many important forcing functions (transmitter variables) that they can not control. There is a frustration with these variables and they would like to see something done about them. Villagers have developed ways of dealing with these changing and difficult conditions, since their cognitive maps are highly adaptive, but there is also a message in these maps to NGO and government officials. Projects which are going to be implemented in the Kizilirmak Delta have to explicitly address the forcing functions that impact their daily lives.

The need to address issues of importance to villagers is also supported by the comparison of 12 most mentioned transmitter variables among villagers and NGO and government officials. The list reveals the different concerns by the mentioned forcing functions (Table 3.). There are only 3 variables that are shared: market forces and middlemen, Bafra wastewater, and dams. The mentioned variables immediately strikes us in terms of what are thought to be controlling the ecosystem. For villagers most of the variables are related to agriculture. Use of pesticide, fertilizer, government subsidies, drainage, irrigation, seeds and fuel prices are direct inputs, enhancing the productivity of agriculture, and are phenomenally all that have made the green revolution possible. Although these elements have made a strong impression on the villagers life and thought processes, they see no control or way of changing these forces. As one villager said: "Maybe we should all gather and walk to the government center, but no one has the courage to do so". The most that they were able to do was shift, and diversify their economic activities, trying to adapt to the changing market forces. In the process, however, they were loosing a considerable amount of income to middlemen. Urban wastewater, dams industrial effluents and air pollution were seen as external factors polluting the environment, changing the climate, thereby causing crop and animal diseases. Water levels were important because high water limits access to the grazing areas around wetlands. These causal relationships show that an environmentalism that encompasses these larger environmental issues as much as biodiversity is more likely to gain the confidence and cooperation of villagers and might be a starting point for dialogue. However the biodiversity component should always be a part of the agenda and must be explained and integrated to the larger issues as far as the villagers would like to incorporate it.

Table 3: The first twelve most mentioned transmitter variables ranked in order.

	NGO and Government Officials	Villagers
1.	Incompetence of protection agencies	Use of pesticides
2.	NGO's inappropriate policy	Industry
3.	County forest protection office	Fertilizer
4.	Siltation	Water level
5.	Reed collection	Market forces - middlemen
6.	Politics and politicial pressures	Bafra wastewater
7.	Market forces - middlemen	Dams
8.	Law enforcement	Government subsidies
9.	Population increase	Drainage
10.	Dams	Irrigation
11.	Bafra wastewater	Quality seeds
12.	Planning and implementation	Fuel prices

When we look at the most frequent transmitter variables mentioned by NGO and government officials we observe that the officials are very reflexive. NGO and government officials recognize the inadequacy of protection agencies in realizing their duty and the inappropriate policies that did not contribute for halting the trend of environmental degradation and loss of biodiversity in the Kizilirmak Delta. They think that some of the external factors, that do not have checks and balances, are causing the degradation of the delta, such as siltation, politics and political pressures, market forces, the level of law enforcement, population increase, dams and pollution. They see mostly reed cutting and planning and implementation as variables that are positive but could be improved upon. All these mentioned forcing functions are seen as controlled by an upper hierarchy operating at the national level. Therefore the NGOs have decided to focus on policy making and lobbying at the level of the central government with the help of the sympathetic bureaucrats working in protection agencies. Thereby they see the solutions to the environmental degradation of the Kizilirmak Delta, as coming from outside the delta.

The Content and Structure of Social Cognitive Maps

Social cognitive maps give a larger and more complete picture of the way in which the stakeholders view the Kizilirmak Delta than individual cognitive maps. Social cognitive maps are more than a simple addition of all the separate cognitive maps, because the individual cognitive maps are already a product of the social cognitive maps as much as they contribute to it. Therefore an analysis that only looks at individual cognitive maps is incomplete. The total number of variables defined in 31 cognitive maps was 136 with 616 connections (Table 4). Out of 136 total variables found in this study, villagers defined 108, vacation home owners 18, NGO officials 58 and the Government officials defined 67 (See Apendix I). Government and NGO officials together defined 84. To get an idea of the variability in variables and connections in another subject area, urban development, Malone (1975) reported that eight graduate students drew a social cognitive map that had 22 variables and 270 connections in a mapping exercise that lasted two and a half hours.

The indices of the social cognitive maps echo the individual cognitive maps in some aspects but are different in others (Table 4). Although we cannot run hypothesis testing statistics on single social cognitive maps, the differences among stakeholder seems to hold except for the number of connections and the resulting connection to variable ratio. The hierarchy index which also takes into account the strength of connections compared to the number of connections in density is different. As individual cognitive maps are augmented the possible number of connections, and the actually drawn connections increase faster than the number of variables. Therefore the resulting social cognitive maps are not a simple reflection of the individual maps. The manifestation of this is the hierarchy index that shows that the social cognitive map of the villagers and vacation home owners is structurally more complex than that of NGO and government officials once they are augmented (Table 4).

Centrality, which is the total indegree reflecting the absolute strength of connections entering and exiting the variables, is an important index that reveals which variables play an important central part in the cognitive maps of the Kizilirmak Delta (Table 5). The similarity between NGO and government officials is striking. They share 9 of the most central 12 variables. All stakeholders have put Agriculture, Livelihood and Fish in a central position. However, NGO and government officials did not consider animal husbandry to be very central, whereas the villagers have put it as the most central variable. One of the major reasons for resistance to protection status from the villagers is the fear that they will not be able to graze their animals in the protected zone. Effective protection, political pressures and

Table 4: Different variable types and indices for social cognitive maps of the stakeholder groups in the Kizilirmak Delta.

	Villagers	Vacation H. Owners	NGO Officials	Government Officials	Total Social Cognitive Map
Number of Variables	108	18	58	67	136
Number of Connections	382	38	190	204	616
Connection to Variable Ratio	3.54	2.11	3.28	3.04	4.53
Number of Transmitter Var.	36	6	11	17	27
Number of Receiver Var.	7	4	7	8	9
Receiver to Transmitter Ratio	0.194	0.667	0.636	0.470	0.333
Density	0.033	0.117	0.056	0.045	0.033
Hierarchy Index	0.030	0.069	0.026	0.021	0.026

law enforcement have been put at a central position by NGO and government officials and was not considered to be important by the villagers. In contrast livelihood is put at a higher central position by the villagers compared to the rest of the stakeholders. Fish are considered at about the same level of centrality by all stakeholders.

Table 5: The most central twelve variables in the social cognitive maps of the stakeholders.

	Villagers	Vacation H. Owners	NGO Officials	Government Officials
1.	**Animal husbandry**	Vacation & rest	**Effective protection**	Ecological importance
2.	***Agriculture***	**Forest**	**Political pressures**	**Effective protection**
3.	***Livelihood***	**Wildlife & birds**	***Agriculture***	***Agriculture***
4.	***Fish***	Watermelons & vegetables	Illegal secondary housing	Pollution
5.	Lagoons	**Animal husbandry**	**SHW (DSI projects)**	**Wildlife & birds**
6.	Use of pesticides	The Black Sea	***Fish***	Law Enforcement
7.	Beach habitat quality	***Fish***	**Law enforcement**	***Fish***
8.	**Game wildlife**	***Agriculture***	Drainage	***Livelihood***
9.	Quality grazing area	Angling	***Livelihood***	**Political pressures**
10.	Rice agriculture	***Livelihood***	**Hunters**	**Hunters**
11.	**Forest**	**Game wildlife**	NGO policy	Research & monitoring
12.	Bafra wastewater	Tar & petroleum	Water Problems	**SHW (DSI) projects**

All variables are ordinary variables except in vacation home owners group "vacation and rest", and "livelihood" are receiver variables, and "tar and petroleum", and "game wildlife" variables are transmitter variables.
Italic, bold and underlined variables are shared by all stakeholders. ***Bold and Italic*** variables are shared by NGO and government officials, **Bold** is shared by two stakeholder groups. Plain font is unique to stakeholder group in the twelve most central variables.

The results of Table 5 indicate that NGO and government officials need to be more sensitive to the issues of animal husbandry, agriculture and livelihood, especially considering that the other central variables in the villagers' social cognitive map are directly related to agriculture and animal husbandry. Effective protection and law enforcement has to be tied into the concerns of the local people. Wildlife and birds, fishing and hunting needs to be addressed together with the villagers. Experiences from community wildlife management projects around the world can be a starting point for government policies and NGO projects. Political pressures are part of a democratic system. However if local support for conservation can be gained, these pressures can be balanced by local politics and its effect on the larger political arena. Local support for conservation projects provides a leverage for lobbying efforts of the NGOs. Currently, the local reaction to conservation projects only hampers the lobbying efforts of the NGOs despite the support of government officials. If long term sustainability is the goal, then conservation can not be achieved without the long-term support of the villagers. Without the support NGOs and government officials will constantly be under political pressures that they see as a central variable in their social cognitive maps.

Condensed Social Cognitive Maps

The social cognitive maps have a large number of variables and connections that make it impractical to evaluate them in graphical form. Therefore the cognitive interpretation diagrams (CIDs) were drawn where 12 variable categories were defined by qualitative aggregation (Appendix II). These twelve variables were connected with 36 connections that had the highest weights. The resulting CIDs (Fig. 4) show that all stakeholders believe there is a strong negative causal decrease in ecosystem health caused by environmental problems (i.e., that environmental problems are serious). NGO and government officials believe that social forces have an important impact on ecosystem health (Fig. 4b,c). However while government officials think that social forces can increase ecosystem health, NGO officials think the social forces impact ecosystem health negatively and have a virtuous cycle with economic forces. Villagers believe that ecosystem health causes an increase in resource use and agricultural production and show an important positive causal relationship from agricultural production and resource use to livelihood (Fig. 4a). Government and NGO officials do not put this important relationship in their social cognitive maps (Fig. 4b,c). Water issues are seen as impacting agricultural production and ecosystem health negatively by NGOs and government officials. The total social cognitive map of all stakeholders captures the most important relationships mentioned in the stakeholder maps and could be used by the parties to come to a common agreement to form a shared conception of how the Kizilirmak Delta ecosystem functions. Once that agreement is achieved it can be a basis for discussions on what the most appropriate policies would be and which management options to pursue to address the concerns of all parties.

Cognitive Map Simulations

Once the cognitive maps are drawn and the adjacency matrix coded, different simulations can be run and "what-if" questions can be asked. The behavior of various models can be observed almost instantly under different scenarios using the neural computational method. In this study alternative management options were run using policy, management (independent) and system response (performance, dependent) variables mentioned by all three stakeholder groups. Shared variables were chosen so that the results will be most relevant to all stakeholder groups. The dependent variables were ecological importance, beach habitat quality, amount of wetland, amount of forest, fish, wildlife and birds, water problems, pollution, drainage, agriculture, animal husbandry, logging, and livelihood. These fall into three categories, ecological importance, environmental problems and livelihood. The independent variables (policy and management options) were market forces, law enforcement, municipality, county forestry office, NGO's inappropriate policies, incompetence of government, effective and sustained protection (Fig. 5).

In the first no management option all variables were set equal to one at the start and were allowed to change and settle to a final value freely. In other options where ecosystem conservation strategies were simulated independent variables were set (clamped, forced) to one at each iteration until the system converged. The results of the social cognitive maps of the stakeholder groups (Fig. 5a,b,c) and their cumulative cognitive map results (Fig. 5d) indicates that the best strategy in general is to apply all policy and management options simultaneously. However the villagers (Fig. 5a) think the best strategy for beach habitat quality, fish and animal husbandry would be strong NGO and government policies that would increase their states. But this strategy would conflict with logging and livelihood, decreasing their state. The social cognitive map of government officials (Fig. 5c) indicates that they think strong government policies, effective and sustained protection is going to be a win-win situation increasing ecosystem importance variables decreasing environmental problems and increasing livelihood states; villager cognitive maps do not agree.

Two characteristics of cognitive maps becomes visible in these simulations, the first one is their emergent properties. The sum of the results of cognitive maps is not the whole, the whole shows different properties when villagers, NGO and government officials maps are augmented to form the total cognitive map of all stakeholders (Fig. 5d). The state of fish and animal grazing is fixed at almost zero under all simulated options because of the compounded negative causal decrease they receive. The second characteristic is related and shows the possibility of synergistic interaction among different management options. For example the different simulation options do not have an effect on the state of ecological importance in the cognitive map of all stakeholders, but when all management options are applied the state will increase to about 0.2 (Fig. 5d).

An overall look into the three categories of dependent variables indicate that all stakeholders' cognitive maps agree that the state of ecological variables (ecological importance, beach habitat quality, amount of wetland, amount of forest, fish, wildlife and birds) is low compared to environmental problems (water problems, pollution) and livelihood (drainage, agriculture, animal husbandary, logging, livelihood) (Fig. 5). However they disagree on how low the level of ecological importance is. The simulations indicate that villagers believe the ecosystem is doing better than NGO officials do. NGO officials think it is doing better than government officials do. However government officials think it can recover by the various policy and management options far better than NGO officials think it can (Fig. 5b,c).

The formal validation of these cognitive maps is not possible because they operate on different understandings of the biophysical and social spheres of the Kizilirmak Delta. They are also qualitative models that do not yield outputs measurable in nature. The question whether some of these maps represent reality better than the others might not be possible because the reality with which the model outputs are compared is mediated through yet another understanding. For example villagers dispute the level of biodiversity assessed by researchers and say that only commonly breeding birds can be used for evaluating the importance of the delta for bird species.

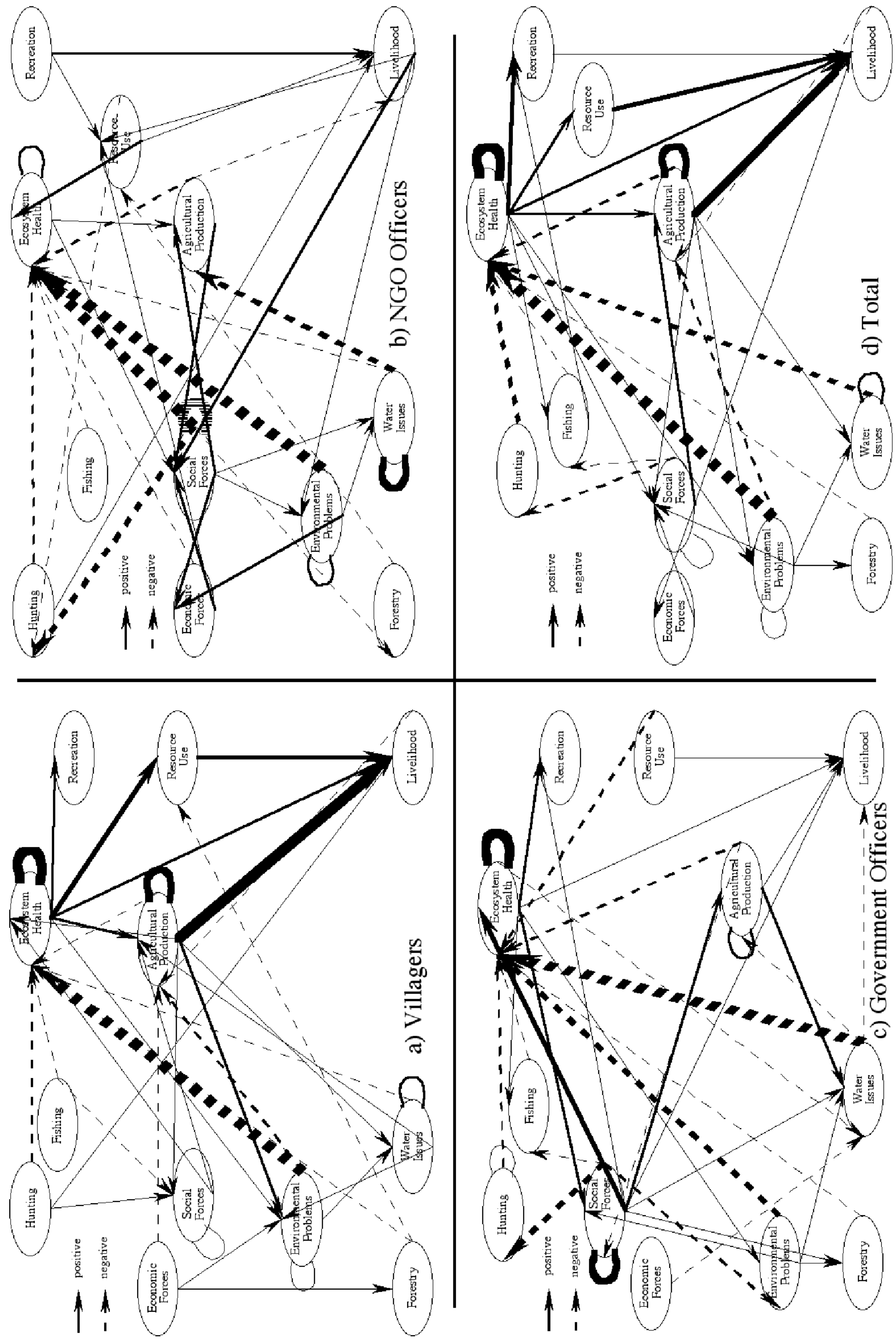


Figure 4: Condensed social cognitive interpretation diagrams (CIDs) of a) villagers, b) NGO officials, c) government officials and d) of all stakeholders. Only the highest 36 connections are shown. Connection arrows have pixel thickness scaled to weights.

As what we know and accept as truth is constantly negotiated in society, the people of the Kizilirmak Delta negotiate what counts as knowledge and what should be included in the models of the Kizilirmak Delta. Villagers reflect upon their environment with their own empiricism and choose and define what counts as knowledge based on their own normative agenda. On the other hand science that has proven to be useful for villagers plays an important part in their cognitive maps as they define variables of the green revolution as transmitter variables in their maps (Table 3). Nevertheless a qualitative validation can be made in terms of a "reality check" rather than formal validation, for example if a map predicts a crash in fish populations and fishing people are having record harvests year after year, then obviously something is wrong with the construction of the model. All stakeholder maps predict that fish stocks are low and villagers do complain that fishing has gone down in the last 20 years. So some level of validation can be achieved. An environmental history that tracks relative changes in variables based both on peoples' perceptions and historical evidence in records provides an excellent medium to conduct these reality checks (Ozesmi 1999).

CONCLUSION

Utility of Fuzzy Cognitive Maps

The complexity encountered in the social cognitive maps of the inhabitants of ecosystems is a humbling experience for the researcher. One is continuously challenged to describe a thought system that has a complexity beyond simple representations. Therefore any summary or cross-section presented is an incomplete picture. A true understanding can only come through careful exploration of the graphical representation of the map, looking at summary indices followed by running endless simulations and observing all the variable changes. This exploration is not reserved for the researcher, but can be done by the stakeholders as well. The maps represent an "epistemological structure" around which stakeholders organize their experience (Cossette and Audet 1992). The drawing of cognitive maps is a "cathartic experience" which enables an articulation of how a stakeholder perceives a system (Eden 1992). The cognitive map in this sense lets the informant who constructs the cognitive map to explore her present and future cognition, which facilitates reflectiveness with its "emancipatory" properties (Cossette and Audet 1992). In addition to the drawing of the map, the careful exploration and simulation of the individual and social cognitive maps has to be considered in a continuum both for the researcher and the stakeholders.

Fuzzy Cognitive Maps for Facilitating Communication

Sustainability has mostly been formulated by some as resistance movements against government agendas to develop an ecosystem for economic gain (Ghai and Vivian 1992). The transformation of the Kizilirmak Delta into a green revolution "paradise" was accomplished in the 1950s and 60s before there were any conservation agendas by NGOs and governments (Ozesmi 1999). In some agricultural systems where humans see themselves as part of nature with moral obligations, they have developed conduct that is geared to achieving a balance (Sandell 1996). This is not the case in the Kizilirmak Delta. There is limited feedback from the wetland ecosystem to economic activities to encourage ecosystem conservation by villagers. Currently the resistance is, rightly so, of villagers against sustainable development that restricts and regulates their economic activity. Yet they also share most of the concerns with NGOs and government agencies about environmental degradation. If there is an overlap inter and intra social cognitive maps of stakeholders, these "may provide a basis for simultaneous unity and diversity in group processes" [emphasis theirs] (Fiol and Huff 1992, p.277). In this way the cognitive maps elicited in this study are representations of subjective experiences enabling the stakeholders and the researcher to gain insight on the subject of study, but more so it is a "tool to facilitate decision-making, problem-solving, and negotiation" (Eden 1992) to achieve a normative goal of conservation. If any conservation policies and ecosystem management is to succeed, it has to take into account the cognitive maps of the villagers and reconcile it with that of NGOs and government officials.

Recovery of Local Knowledge, Realism, and Ethics

The cognitive maps indicate that villagers have significantly larger number of variables, more complex maps, a broader understanding of all the variables that affect the Kizilirmak Delta, and mention more variables that control the ecosystem. They have developed a large adaptive capacity to changing ecological and social conditions. They actively change and challenge these conditions through the political process. Villagers are faced with many important forcing functions that they cannot control. Most of their variables are related to agriculture and animal husbandry. This shows that conservation policies and ecosystem management must encompass these larger environmental issues as much as biodiversity. One of the major reasons of resistance against a protection status from the villagers is the fear that they will not be able to graze their animals in the protected zones. NGOs and government officials must gain the confidence and cooperation of villagers by addressing these issues. After this has been accomplished it provides a starting point for dialogue. Cognitive maps can serve as a basis when policies and management options are discussed. A villager-centered cognitive mapping approach is not only necessary because of villagers' resistance or because top down projects that do not take into account local knowledge systems fail, but because it is the ethical and responsible way of doing ecosystem management.

ACKNOWLEDGEMENTS

I would like to thank the inhabitants of the Kizilirmak Delta wetlands, Huseyin and Musa Bas, Fatma and Ahmet Altintas, Isa Eroglu and many others. Without the valuable information they shared with me this research would have been impossible. I am particularly grateful to Sunay Demircan and Sancar Baris for their constant support of this project. The text benefited immensely from the comments of Herbert A. Simon, William P. Cunningham, Phillip Regal, David Bengston, Stacy Ozesmi, and Dale Trexel. This research was funded in part by the MacArthur Program on Global Change, Sustainability, and Justice, and the Conservation Biology Program of the University of Minnesota.

REFERENCES

Akkan, E. 1970. Bafra Burnu - Delice Kavsagi Arasindaki Kizilirmak Vadisinin Jeomorfolojisi (The geomorphology of the Kizilirmak Valley between Bafra penninsula and Delice joint). Ankara University School of Language and History - Geography Publications: 191, Ankara.

Alkim, U. B., H. Alkim, and O. Bilgi. 1988. Ikiztepe I: The First and Second Seasons' Excavations (1974-75). Turk Tarih Kurumu Basimevi, Ankara.

Alkim, U. B., H. Alkim, and O. Bilgi. 1999. Ikiztepe II: Excavation Report of Seasons 1976-1980. TÃ¼rk Tarih Kurumu Basimevi, Ankara.

Anderson, J. 1983. The Architecture of Cognition. Harvard University Press, Cambridge, MA.

Axelrod, R. 1976. Structure of Decision, The Cognitive Maps of Political Elites. Princeton University Press, Princeton, NJ.

Bateson, G. 1972. Steps to an Ecology of Mind. Bantam Books, New York.

Bateson, G. 1979. Mind and Nature: A Neccessary Unity. Bantam Boooks, New York.

Bauer, V. 1975. Simulation, Evaluation and Conflict Analysis in Urban Planning, Pages 179-192 in M. M. Baldwin, editor. Portraits of Complexity: Applications of Systems Methodologies to Societal Problems. Batelle Institute, Columbus, OH.

Biggs, N. L., E. K. Lloyd, and R. J. Wilson. 1976. Graph Theory 1736-1936. Clarendon Press, Oxford.

Bougon, M., K. Weick, and D. Binkhorst. 1977. Cognition in organizations: an analysis of the Utrecht Jazz Orchestra. Administrative Science Quarterly 22:606-639.

Brown, S. M. 1992. Cognitive Mapping and Repertory Grids for Qualitative Survey Research: Some Comparative Observations. Journal of Management Studies 29:287-307.

Buede, D. M., and D. O. Ferrell. 1993. Convergence in Problem Solving: A Prelude to Quantitative Analysis. IEEE Transactions on Systems, Man, and Cybernetics 23:746-765.

Carley, K. 1986. An approach for relating social structure to cognitive structure. Journal of Mathematical Sociology 12:137-189.

Carley, K. 1988. Formalizing Social Expert's Knowledge. Sociological Methods and Research 17:165-232.

Carley, K. 1997. Extracting Team Mental Models Through Textual Analysis. Journal of Organizational Behavior 18:533-558.

Carley, K., and M. Palmquist. 1992. Extracting, Representing, and Analyzing Mental Models. Social Forces 70:601-636.

Coles, J., and B. Coles. 1992. The Wetland Revolution: A Natural Event, Pages 147-153 in B. Coles, editor. The Wetland Revolution in Prehistory. The Prehistoric Society, London.

Cossette, P., and M. Audet. 1992. Mapping of an Idiosyncratic Schema. Journal of Management Studies 29:325-347.

Craiger, J. P., R. J. Weiss, D. F. Goodman, and A. A. Butler. 1996. Simulating organizational behavior with fuzzy cognitive maps. International Journal of Computational Intelligence and Organizations 1:120-133.

Dickerson, J. A., and B. Kosko. 1994. Virtual worlds as fuzzy cognitive maps. Presence 3:173-189.

Eden, C. 1988. Cognitive Mapping. European Journal of Operational Research 36:1-13.

Eden, C. 1992. On the Nature of Cognitive Maps. Journal of Management Studies 29:261-265.

Eden, C., F. Ackerman, and S. Cropper. 1992. The Analysis of Cause Maps. Journal of Management Studies 29:309-323.

Eden, C., S. Jones, and D. Sims. 1979. Thinking in Organizations. The Macmillan Press, London.

Fiol, C. M., and A. S. Huff. 1992. Maps for Managers: Where are we? Where do we go from here? Journal of Management Studies 29:267-285.

Ghai, D., and J. M. Vivian. 1992. Grassroots Environmental Action: Peoples Participation in Sustainable Development. Routledge, New York.

Hage, P., and F. Harary. 1983. Structural models in anthropology. Oxford University Press, New York.

Hannigan, J. A. 1995. Environmental Sociology: A social constructionist perspective. Routledge, New York.

Harary, F., R. Z. Norman, and D. Cartwright. 1965. Structural Models: An Introduction to the Theory of Directed Graphs. John Wiley & Sons, New York, NY.

Hart, J. A. 1977. Cognitive Maps of Three Latin American Policy Makers. World Politics 30:115-140.

Hustings, F., and K. v. Dijk. 1993. Bird Census in the Kizilirmak Delta, Turkey in Spring 1992. WIWO-report 45, Zeist, The Netherlands.

Iwasaki, Y., and H. A. Simon. 1994. Causality and model abstraction. Artificial Intelligence 67:143-194.

Jerison, H. J. 1973. The Evolution of the Brain and Intelligence. Academic Press, New York.

Kim, H. S., and K. C. Lee. 1998. Fuzzy Implications of Fuzzy Cognitive Map with Emphasis on Fuzzy Causal Relationships and Fuzzy Partially Causal Relationship. Fuzzy Sets and Systems 97:303-313.

Klein, J. H., and D. F. Cooper. 1982. Cognitive maps of decision-makers in a complex game. Journal of the Operational Research Society 33:63-71.

Kosko, B. 1986. Fuzzy cognitive maps. International Journal of Man-Machine Studies 1:65-75.

Kosko, B. 1987. Adaptive Inference in Fuzzy Knowledge Networks, Pages 261-268, Proceedings of the First IEEE International Conference on Neural Networks (ICNN-86), San Diego, California.

Kosko, B. 1988. Hidden Patterns in Combined and Adaptive Knowledge Networks. Proceedings of the First IEEE International Conference on Neural Networks (ICNN-86) 2:377-393.

Kosko, B. 1992a. Fuzzy Associative Memory Systems, Pages 135-162 in A. Kandel, editor. Fuzzy Expert Systems. CRC Press, Boca Raton, Florida.

Kosko, B. 1992b. Neural Networks and Fuzzy Systems: A Dynamical Systems Approach to Machine Intelligence. Prentice-Hall, Englewood Cliffs, New Jersey.

Langfield-Smith, K. 1992. Exploring the Need for a Shared Cognitive Map. Journal of Management Studies 29:349-367.

Laszlo, E., R. Artigiani, A. Combs, and V. Csanyi. 1996. Changing Visions, Human Cognitive Maps: Past, Present, and Future. Praeger, Westport, Connecticut.

MacDonald, N. 1983. Trees and Networks in Biological Models. John Wiley and Sons, New York.

Malone, D. W. 1975. An Introduction to the Application of Interpretive Structural Modeling, Pages 119-126 in M.

M. Baldwin, editor. Portraits of Complexity: Applications of Systems Methodologies to Societal Problems. Batelle Institute, Columbus, OH.

Montazemi, A. R., and D. W. Conrath. 1986. The use of cognitive mapping for information requirements analysis. MIS Quarterly 10:45-55.

Nakamura, K., S. Iwai, and T. Sawaragi. 1982. Decision Support Using Causation Knowledge Base. IEEE Transactions on Systems, Man, and Cybernetics SMC-12:765-777.

Ozesmi, S. L., and U. Ozesmi. 1999. An artificial neural network approach to spatial habitat modelling with interspecific interaction. Ecological Modelling 116:15-31.

Ozesmi, U. 1992. Recent facies in the lagoon barrier east of the Kizilirmak Delta (Samsun) and ideas on its formation. Geological Engineering Department, Middle East Technical University, Ankara.

Ozesmi, U. 1999. Environmental History Through Faults: Past and Present Resource Use in the Kizilirmak Delta. unpublished manuscript.

Ozesmi, U. 2003. The ecological economics of harvesting sharp-pointed rush (Juncus acutus) in the Kizilirmak Delta, Turkey. Human Ecology 31 (4): 645-655.

Ozesmi, U., and C. Karul. 1990. Bird Observations in the Kizilirmak Delta, September - 1989, Ankara, Turkey.

Palmquist, M. E., K. M. Carley, and T. A. Dale. 1997. Applications of Computer-Aided Text Analysis: Analyzing Literary and Nonliterary Texts, Pages 171-189 in C. W. Roberts, editor. Text Analysis for The Social Sciences: Methods for Drawing Statistical Inferences from Texts and Transcripts. Lawrence Erlbaum Associates, Publishers, Mahwah, NJ.

Radomski, P. J., and T. J. Goeman. 1996. Decision Making and Modeling in Freshwater Sport-fisheries Management. Fisheries 21:14-21.

Rappaport, R. A. 1979. Ecology, Meaning, and Religion. North Atlantic Books, Richmond, CA.

Reimann, S. 1998. On the design of artificial auto-associative neural networks. Neural Networks 11:611-621.

Resmi-Gazete. 1998. Sulak Alanlar Tebligi,, Pages 25-28, Teblig No:3. Turkiye Cumhuriyeti, Ankara.

Roberts, F. S. 1973. Building and Analyzing an Energy Demand Signed Digraph. Environment and Planning 5:199-221.

Sandell, K. 1996. Sustainability in theory and practice: a conceptual framework of eco-strategies and a case study of low-resource agriculture in the dry zone of Sri Lanka, Pages 163-197 in A. Hjort-af-Ornas, editor. Approaching Nature from Local Communities: Security Percieved and Achieved. Linkoping University, Linkoping, Sweden.

Schneider, M., E. Shnaider, A. Kandel, and G. Chew. 1998. Automatic construction of FCMs. Fuzzy Sets and Systems 93:161-172.

Simon, H. A. 1996. The Sciences of the Artificial. The MIT Press, Cambridge, MA.

Styblinski, M. A., and B. D. Meyer. 1988. Fuzzy Cognitive Maps, Signal Flow Graphs, and Qualitative Circuit Analysis, Pages 549-556, Proceedings of the 2nd IEEE International Conference on Neural Networks (ICNN-87), San Diego, California.

Taber, W. R. 1991. Knowledge processing with fuzzy cognitive maps. Expert Systems With Applications 2:83-87.

Taber, W. R., and M. A. Siegel. 1987. Estimation of expert weights using fuzzy cognitive maps, Pages 319-325, Proceedings of the First IEEE International Conference on Neural Networks (ICNN-86).

Tekkaya, I., and S. Payne. 1988. The Mammalian Fauna of Ikiztepe, Pages 227-244 in U. B. Alkim, H. Alkim and O. Bilgi, editors. Ikiztepe I: The First and Second Seasons' Excavations (1974-75), V. Dizi Sayi 39 ed. Turk Tarih Kurumu Basimevi, Ankara.

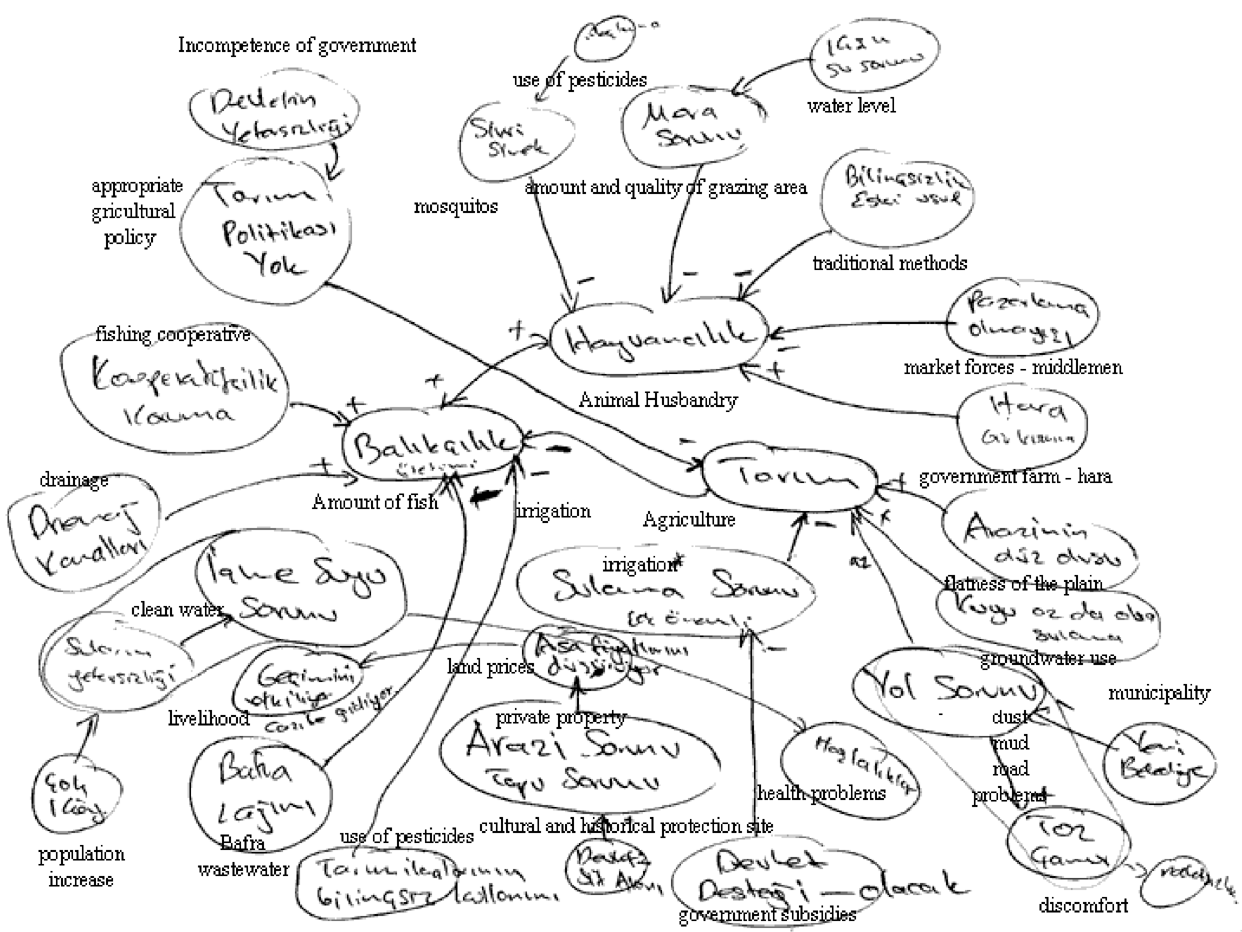
Tolman, E. C. 1948. Cognitive maps in rats and men. Psychological Review 55:189-208.

Wrightson, M. T. 1976. The documentary coding method, Pages 291-332 in R. Axelrod, editor. Structure of Decision, The Cognitive Maps of Political Elites. Princeton University Press, Princeton, NJ.

Zhang, W.-r., and S.-s. Chen. 1988. A logical architecture for cognitive maps, Pages 231-238, IEEE International Conference on Neural Networks, San Diego, California.

Appendix I

Cognitive map drawn by a villager with corresponding variable translations.



Appendix II

Table of all variables and the stakeholder groups that have included the variables in their cognitive maps, showing whether variables are transmitter (T), receiver (R) or ordinary (O), and the centrality of variables scaled between 0 and 1. Variables in bold are shared at least by villagers, NGO and government officials.

	Total	Villagers	Vacation Home Owners	NGO Officials	Government Officials
Eco-system health	**Ecological importance**	R-0.04		R-0.30	O-1.00
	Natural beauty	R-0.04			O-0.14
	The Black Sea	T-0.06	O-0.31		R-0.03
	Beach habitat quality	O-0.25		O-0.20	O-0.10
	Kizilirmak River				R-0.03
	Lagoons	O-0.56			O-0.22
	Amount of wetland	O-0.08		O-0.36	R-0.05
	Water level	T-0.12			
	Amount of thorny shrubs	O-0.03			
	Amount of forest	O-0.18	O-0.54	R-0.20	O-0.16
	Flatness of the plain	T-0.01			
	Amount of leech	O-0.05			
	Amount of crayfish	O-0.06			
	Amount of fish	O-0.67	O-0.31	O-0.64	O-0.35
	Amount of wildlife - birds	O-0.08	O-0.38	O-0.33	O-0.40
	Amount of game wildlife	O-0.23	T-0.15	O-0.08	
Environ-mental problems	Desertification	O-0.09			
	Coastal erosion	T-0.01		O-0.15	R-0.05
	Sand gravel extraction	O-0.03		T-0.15	O-0.05
	Soil extraction from dunes	T-0.03			
	Tar - petroleum pollution	T-0.01	T-0.08		
	Use of pesticides	O-0.26			
	Bafra wastewater	O-0.17			O-0.11
	Vegetation overgrowth	O-0.08			
	Mosquitos	O-0.14			
	Industry	T-0.16			O-0.08
	Dams	T-0.05		T-0.05	O-0.08
	Illegal secondary housing	O-0.10		O-0.76	O-0.19
	Health problems	R-0.08			
	Population increase	T-0.03		T-0.20	O-0.11
	Unsustainable land and resource use			O-0.33	O-0.05
Water Issues	**Water problems**	O-0.05		O-0.42	O-0.13
	Siltation	O-0.17			T-0.11
	Pollution	O-0.10		R-0.10	O-0.41
	Clean Water	O-0.04			
	Groundwater use	O-0.08			O-0.08
	Irrigated agriculture	O-0.16		O-0.40	
	Irrigation			O-0.36	O-0.08
	Drainage	O-0.12		O-0.62	O-0.05
	Collector Drainage Channel	T-0.09			O-0.05
Agri-cultural pro-duction	Agricultural production and importance	O-0.16			
	Agriculture	O-0.96	O-0.31	O-0.78	O-0.55
	Rice agriculture	O-0.19			O-0.11
	Watermelons and vegetables	O-0.12	O-0.38		R-0.03
	Experimenting with seeds	O-0.04			

	Quality seeds	O-0.06			
	Fertilizer	O-0.13			T-0.05
	Mechanization	T-0.01			
	Traditional methods	T-0.05			
	Bad and unpredictable weather	O-0.16		T-0.05	
	Crop diseases	O-0.13			
	Land ownership disputes	O-0.04		O-0.15	
	Development cooperative	T-0.03			
	Agricultural extension	O-0.05		T-0.04	T-0.03
	Pesticide and fertilizer companies	O-0.03			
	Animal husbandry	O-1.00	O-0.38	O-0.29	O-0.15
	Improving animal breeds	O-0.04			
	Feed prices	0-0.10			
	Amount and quality of grazing area	O-0.22		R-0.05	T-0.03
	Animal diseases	O-0.16			
	County veterinarian service	T-0.03			
Fishing	Angling		O-0.23		O-0.05
	Fishing cooperative	O-0.04			T-0.03
	Number of fishing coop members	T-0.03			
	Amount of fishing gear	O-0.03			
	Fishing with light projectors	T-0.01			
	Fish size limitations	T-0.03			
	Fishing out of order and time	O-0.04	T-0.08	T-0.05	O-0.08
	Crayfish disease	T-0.03			
	Resting the lakes	O-0.03			
Hunting	**Hunters**	O-0.06		O-0.49	O-0.30
	Poaching	T-0.03	T-0.08	O-0.18	O-0.14
	Hunting out of tradition	T-0.03			
	Amount of hunters fro m the outside	T-0.03	T-0.08		T-0.03
	Automatic shotguns	T-0.01			T-0.03
Forestry	Planting trees	O-0.04			
	Logging of forest	O-0.13	T-0.08	O-0.15	O-0.16
Resource use	Sustainable livelihood			O-0.25	
	House construction	R-0.01			
	Heating - firewood need	R-0.03	R-0.08	R-0.05	
	Natural gas	O-0.03			
	Thatch	R-0.01			
	Juncus harvest	O-0.10			
	Reed harvest	O-0.17		O-0.20	T-0.11
	Flower bulb harvest	O-0.03			
	Frog harvest	O-0.08			
Recreation	**Tourism**	R-0.10		T-0.05	R-0.14
	Vacation, rest and str ess relief		R-1.00		
	Eco-ornito-tourism	O-0.02		O-0.28	O-0.08
Livelihood	**Livelihood**	O-0.68	R-0.23	O-0.58	O-0.35
	Land prices	O-0.03			
	Fuel prices	T-0.04			
Economic Forces	**Market forces - middlemen**	T-0.06		O-0.36	T-0.05
	Inflation	T-0.01			

	Investment for protection			O-0.27	O-0.10
Social Forces	**Law enforcement**	0-0.09		O-0.64	O-0.38
	State Hydraulic Works projects			O-0.74	O-0.24
	Government farm - Hara	T-0.02			
	Municipality	T-0.04		O-0.30	T-0.03
	Forest management			O-0.16	
	County fores t protection office	T-0.01		T-0.08	T-0.11
	County fisheries office	T-0.01			
	NGO's inappropriate policy	T-0.01		O-0.44	T-0.08
	Incompetence of government	T-0.01		O-0.25	O-0.15
	Incompetence of protection agencies			T-0.36	T-0.08
	Effective and sustai ned protection	T-0.05		O-1.00	O-0.63
	Planning and implementation				O-0.21
	Need to protect				R-0.09
	Time to protect				O-0.09
	Cultural and historical protection site				T-0.05
	Inappropriate agricultural policy	O-0.03		O-0.09	
	Government subsid ies	O-0.10			
	Condemning empty land	O-0.03			R-0.03
	National economy policies			O-0.18	
	Research and monitoring			O-0.08	O-0.29
	Analysis				O-0.22
	Politics and political pressures			O-0.92	O-0.33
	Patronage and lack of enforcement	T-0.01			O-0.05
	Organized crime on land speculation	T-0.01		O-0.20	
	Education				O-0.09
	Cooperation			O-0.13	
	Contribution			O-0.17	
	Social consciousness and approach			O-0.24	
	Media and advertisement	T-0.01			
	Private property				T-0.03
	Non-agricultural private property	O-0.03			
	Small land holdings	T-0.06			T-0.03
	Pioneer tradition			T-0.05	
	Conflict with nature			R-0.36	
	Human desires			T-0.05	T-0.03
	Beauty of life and living		R-0.08		
	Discomfort	O-0.03			
	Dust, mud, road problems	O-0.08			
	Cultural and social change			O-0.13	
	Festivals	O-0.02			
	Emmigration	O-0.04		R-0.05	
	Total 136	108	18	58	67