

DISSERTATION

HUMAN ENVIROMENT INTERACTIONS AND
COLLABORATIVE ADAPTIVE CAPACITY BUILDING
IN A RESILIENCE FRAMEWORK

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ABSTRACT

HUMAN ENVIROMENT INTERACTIONS AND COLLABORATIVE ADAPTIVE CAPACITY BUILDING IN A RESILIENCE FRAMEWORK

Being firmly in the *Anthropocene Era*—a period in humanity’s evolution where human behavior and dominance is significantly impacting the earth’s systems, my research objective was in response to the concern and call of the National Science Foundation and of the International Human Dimensions Programme on Global Environmental Change that humanity needs to develop new strategies to tackle complex anthropogenic issues impacting the global environment and that there should be a focus on human behavior to effect change.

Through a collaborative tri-phase dual model research initiative in the backcountry of Burntwater, Arizona in the Houck Chapter on the Navajo Nation, a small group of Navajo, using a photovoice and artvoice technique, began an exploration into community issues and concerns. The outcome confirmed that illegal trash dumping was a serious matter to the community in need of attention. Through multiple community gatherings the illegal trash dumping issue was discussed and explored within the workings of a *Participatory Social Frame Work of Action – Collaborative Adaptive Capacity Building* (PSFA-CACB) conceptual model. Using data from my field site I was able to partially inform a theoretical agent-based model *Taking Care of the Land – Human Environment Interactions* (TCL-HEI). Using the TCL-HEI model, I was then able theoretically to illustrate within a resilience framework a social-ecological system

regime basin shift from an undesirable state to a desirable state. This shift resulted from a change in the system's stability landscape variables through the introduction of a combination of consultative behavior and economic incentive model parameters. The ultimate objective of the tri-phase dual-model approach was to show how local and regional sustainable entrepreneurial and cooperative action might change illegal trash dumping behavior through a recycling and waste-to-fuels processing program. I further show how the effect of such an initiative would result in mitigating environmental degradation by lessening illegal trash dumping sites and landfill deposits while creating jobs and empowering a local population.

It is my hope that officials at the Chapter, Agency and Nation levels on the Navajo Nation might consider the ramifications of this study and explore possibilities of contracting-out for the development of a clean-energy waste-to-fuels processing facility and program.

ACKNOWLEDGEMENT

Without a true sense of collaboration and accompaniment on many levels at different times throughout the duration of pursuing this PhD, I truly believe it would not have come to its final fruition. This is not only a recognition of the assistance, leadership, guidance, support and encouragement I have experienced from so many people along the way but it is equally a testament to the powerful force of collaboration in making things happen and getting things done. For true collaboration to occur there needs to be a measure of giving and sharing, of self-sacrifice and I thank all those who put out on my behalf towards this project. Humans are a social and collaborative species and the greater our efforts go towards working together in unity, the greater will be the fruits of our labor on this planet.

First, I acknowledge those at my field site. To the many beautiful Navajo who supported this initiative from its inception as participants. I am deeply grateful for your trust in me, without which this exploration would not have happened. I cannot mention you all but you know who you are, and I thank you. However, to some of you I would like to thank specifically. Chester, you have given so much to your community and still you just keep on giving. You are a man of great wisdom, humility and patience and I have been so fortunate to have been in the presence of one of the great Navajo elders. I will remember our chat together in your beautiful Hogan, thank you. Verna and Andy, from the first evening we sat together in Alice and Jerry's trailer home to discuss this project I marveled at your deep insight and wisdom. Thank you for your support along the way and making me laugh so much. Jon, I will always remember the time we sat up on the hill above Sanders waiting for your daughter and we talked at length about many

of the issues the people of Houck are struggling to overcome. I hope you have forgiven me for losing you at the Orlando Airport during the SED conference we attended. Rose Marie, thank you for all those wonderful meals you cooked in the Big Hogan—your food was nourishing and brought me happiness. I will not forget our little road trip to see your brother back home during the blizzard. My jeep barely made it through the heavy snow and foot deep mud trenches as we slid from one side to the other. Alice and Jerry, what wonderful and incredible support you have given me over the course of this project; truly it is incalculable. Without your seeing my vision from the beginning and believing in me, I would not be standing where I am today. I will always remember our moments of laughter and joy. How you, Alice, sat with me during my very first meeting at the Houck Chapter seeking a resolution. I never told you but I was quite nervous. Jerry, so many great moments; how about the one when we kicked around the water melon rind with the dog at the Chapter House one late hot summer afternoon waiting for just one person to show up for the launch of Phase-I, wow! We have come a long way since then. Anna and to all the NABI staff who supported me during so many trips out, thank you all for your assistance love and support. To the Houck Chapter Governing Board, you have my great appreciation and thanks for granting me the resolution that allowed me this opportunity to work within your Chapter. My hope is that you and the people of Houck benefit from some future emergent opportunity that might arise from this research. Finally but certainly not least, I wish to thank the Navajo Nation Human Research Review Board for accepting my proposal, granting me permission to work on the Navajo Nation with the beautiful people of the Navajo and for patiently assisting me to meet your requirements.

At Colorado State University, I would especially like to recognize my committee for supporting and believing in this initiative. To my Advisor, Dr. Kathleen Galvin; I am truly grateful for all you have done to assist me with my work. Your expertise and refined skills with your work in East Africa has added value to my ability to work here in the United States among the Navajo. You advised me with great patience and wisdom guiding me on the larger issues while allowing me to struggle and grow with the detail. This has certainly been a capacity building experience for me and I thank you for that. Dr. Randall Boone, I am indebted for all of your encouragement and support in the arena of programming—an area I had never ventured into but am very glad I had the nerve to go through with it. It was tough but very rewarding in the end. To my other committee members, Dr. Robin Reid, Dr. Jessica Thompson, and Dr. Jim Banning—I thank you all for your support, encouragement and wise council during our many meetings over this topic.

There are also those who were real intellectual entrepreneurs who put their faith and trust in me from the very beginning, even before I knew I had been accepted into the Graduate Degree Program in Ecology at Colorado State University. I thank all of you for your encouraging support and advice that pushed me along to take the leap: Dr. Muin Afnani, Dr. Doug Allen, Dr. Dwight Allen, Dr. Farzam Arbab, Dr. Vahid Behmardi, Mr. Ken Bowers, Dr. Greg Graff, Dr. Michael Karlberg, Dr. Andrew Keller, and Dr. Jack Keller.

Finally but certainly most deservedly, I have my beautiful family who had to put up with endless late nights, a dirty office, grumpy moods, my long trips, and periods of quiet and solitude as I disappeared to plunge into deep thought. To my infinitely patient

wife, the fact that you still smile at me and laugh with me is a testament to your nobility. Without your support and sacrifice, none of this would have been possible—thank you dear. To my two beautiful sons, you are like paradise and light unto my eyes. You were still boys when I started and now you are young men and no, despite what you might be thinking, I did not take that long to finish...you just grew up too fast. I am going to miss those late-night-into-the-early-morning study episodes we shared—thank you for holding the fort down so well during my many trips into the field. I hope one day to be at your PhD graduation.

To all who assisted me!

Thank You!

Ya'at'eeh!

and may you

Walk in Beauty!

In loving dedication to

Bushra, Ridvan and Nur

PREFACE

This preface is addressed to all those who have contemplated pursuing a PhD or are in a program and thinking of giving up. Of course, every circumstance is unique and you alone can be the judge but here are a few thoughts on my personal experience and overcoming a thousand excuses and times when I would ask myself what am I, at the age of 51, doing? What in the world have I gotten myself into? Make no mistake, pursuing a PhD is a serious commitment and challenging. As many pitfalls and perils as there are, there are also numerous moments of joy, hope and awe. It is a journey and a process, not an event for a diploma that one might just hang on the wall.

At the outset, I kept hearing various humorous descriptions for the PhD acronym. In fact I was first introduced on the Navajo Nation as “the one who is pursuing his degree in *Post hole Digging*”. Then there is the well-known one of *Piled high and Deep* as the culminating achievement along the educational continuum from High School (HS) Bachelor of Science (BS) and Master of Science (MS). I will refrain from expounding on these acronyms except to say that if this were the case, I might consider myself to be well fertilized. However, it was not until someone came to me in a conference and gave me an explanation that spoke to the truth of the matter—a PhD is *Pure hearted Devotion*. It is not the PhD itself but the process of striving for excellence, going beyond what one may think she or he is even capable of—it is striving and choosing not to settle for mediocrity. In the end, the process itself is all about—capacity building (a central theme to this Dissertation). Even if one does not actually obtain the PhD in the end, all is not lost if one approaches the process with an attitude of capacity building and striving for excellence. In so doing, each day one applies oneself towards this aim is a day one has increased

one's capacity and sharpened the edge of excellence and that makes it a day superior to the previous and from this; others can learn and build capacity.

Now to all those post-fifty years of age pursuers of higher education I take my hat off to you. It is not an easy task; let alone to be pursuing such a goal when the physical capabilities are waning—trust me. Furthermore, going back to a classroom environment after having been out for decades can be a daunting experience. I recall my first day of class as being quite an awkward feeling sitting with students whose ages were twice less than mine was. Then there are the advances in technology. This may not be an issue for future generations but I had to cross the great technology divide of having completed my former degrees in the pre-computerized world. Then, I reentered the academic world where all were savvy and in the know on the latest devices and applications which move the fast paced academia world forward. Well, I did it. I stuck it out despite the harrowing first semester when every night I practically told myself “this is crazy!” Although I have not had the honor or privilege of being in the Himalayas, I can equate my first semester back at school to being on the Khumbu Ice Falls of Everest. As on Everest where many adventurers never make it past the Ice Falls, many who venture back to higher education and learning never make it past the first semester. I mention this only to say don't quite. Leave yourself open to change and be flexible but don't quite. Let the reason for your not moving forward be the act of another upon you and not you upon yourself. This is what I often told myself and so I struggled through my doubts and overcame the force of inertia pulling me back to a previous way of life and my known comfort zones. Now, nearly 36 months later; having survived tens of thousands of road miles to my field site where I bore winter's ice, summer's flames, and a mugging that threatened to leave me for dead

in a back-road rural ditch; been honored to climbed the four sacred Navajo-Hopi mountains; passed my harrowing prelim exams having never taken an oral before; kept my marriage intact and my business of six employees afloat; survived a surgery; and,

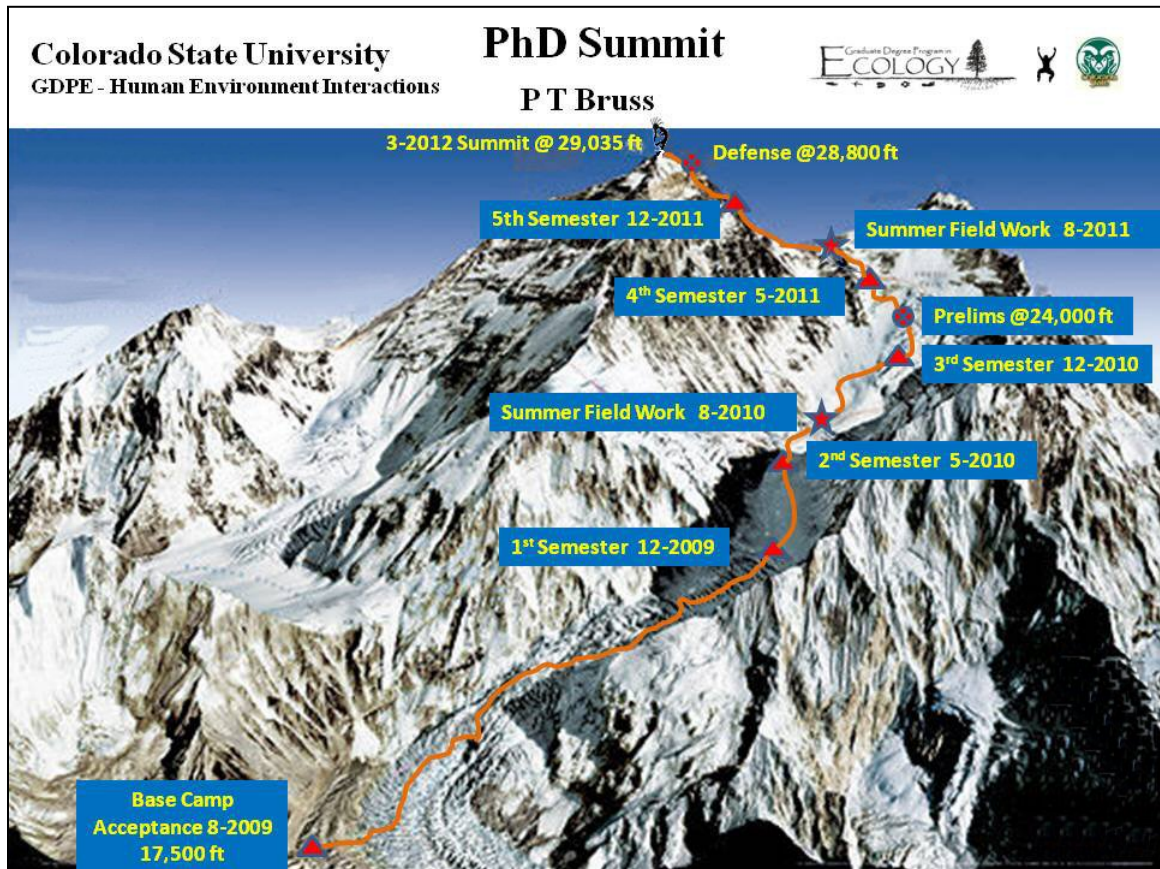


Photo source: National Geographic

managed to steer my two boys through the perils of public high school...I find myself at the summit having just negotiated the final 40 foot ice face, the Hillary Step—my defense. None of this would have been possible without the support and encouragement of so many others, some of whom I gratefully mention in the Acknowledgement section.

From the beginning, I knew this would be my Everest of academics and so I chose to track my progress accordingly commencing at base camp in August 2009. Having climbed many of Colorado’s 14ners, using a mountain metaphor is meaningful and useful

to me. Drawing on my climbing experiences is what has pulled me through many of the difficult times. The higher one gets the more difficult the climb becomes to where all that one can think of in the moment is where and how to place the next step. Knowing that the summit is somewhere up there out of sight, the next step is what counts if one is going to make progress towards that ultimate goal.

Having reached the summit, now what? Well, just like those intense moments of a summit when nothing else seems to exist except you, the mountain and the thought of where to place the next step; when suddenly the eye beholds a spectacular view, it is then that one realizes there is so much more. Therefore, in a sincerely humble posture of learning I stand awe struck at how much I truly do not know compared to what exists in the world of learning and our marvelous Universe—so much awaiting discovery, Carpe Diem!

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CHAPTER 1

INTRODUCTION: A TRI-PHASE DUAL-MODEL COLLABORATIVE FIELD EXPLORATION

We cannot segregate the human heart from the environment outside us and say that once one of these is reformed everything will be improved. Man is organic with the world. His inner life moulds the environment and is itself also deeply affected by it. The one acts upon the other and every abiding change in the life of man is the result of these mutual reactions (Effendi, 1933).

The pursuit of a doctorate and hence this dissertation date back to August 2009. Over the course of the first two years my ideas and concepts revolved around a core interdisciplinary interest of renewable energy, people and how people interact with their natural environment. During the early days of my inquiries into this broad field, I began a high-level review on how algae production could be harnessed as a second-generation biofuel feedstock in a rural regional clean-energy economy. As I worked with my advisor on this theme in a possible East African field setting I soon began to experience the reality of graduate school without external funding during tight economic times. Due to force of economic circumstance, I made a practical decision to reign in my grandiose geographical dream of East Africa and to begin looking locally within the United States. It was during this process and in concurrence with classes and readings that I realized there is a common denominator cutting across all of the social-ecological problems that humanity is facing—people, i.e., humanity’s environmental problems are fundamentally anthropogenic. I then saw the error of my ways, that by taking a *technology-first people-second* approach I had my research focus upside down.

During the process of unpacking and repacking my thinking on this realization I conceptualized a collaborative field study that could empower and build capacity within individuals to explore their own environment and identify issues and concerns that matter most to them, followed by an exploration for potential solutions. I also realized that such an approach would not necessarily be place-dependent but could in fact be applied anywhere there are people. However, through my readings on sustainability and indigenous knowledge I was most interested in trying to pursue this project among Native Americans given their traditional values of respect towards *Mother Earth*. After several failed attempts to try to establish a linkage with Native American populations of the Sioux and Ute in South Dakota and Colorado respectively, I came across an opportunity to work with the Navajo in the rural community of Burntwater within the Houck Chapter on the Navajo Nation. This opportunity was made possible entirely through the encouragement and support of the Native American Baha'i Institute located in Houck (see Chapter 3 for detail on NABI). In hindsight, I see the evolutionary process of landing my research field site on the Navajo Nation quite extraordinary. In hindsight I now often wonder that perhaps it was not mere coincidence that on the day I decided to pursue a PhD in ecology I witnessed a beautiful rainbow in the open preserve behind my home—a symbol of great importance and significance to the Navajo.

RESEARCH PROBLEM

Population growth coupled with unparalleled material and economic development has brought about what many in the scientific community are calling the *Anthropocene Era*¹—a period in humanity's evolution where human behavior and dominance is

significantly impacting the earth's systems. If human behavior is recognized as a root cause for our present global environmental predicament, then it seems not only logical, but imperative to address human behavior as part of an integrated search for long-term sustainable solutions. Such a view is supported by The International Human Dimensions Programme on Global Environmental Change (IHDP, 2010):

Human actions currently dominate the Earth's great biophysical cycles, and are, in aggregate, responsible for a variety of large-scale environmental changes from climate change to loss of biodiversity or changes in the land cover. There is no way to address such problems effectively without altering human behavior individually and collectively. It is no exaggeration to say that the Earth is moving into an era properly called the Anthropocene. Through this knowledge, it has become clear that addressing large-scale environmental issues, and fostering sustainable development will require a concerted effort on the part of researchers who focus on human behavior.

Because of the seriousness of these phenomena, the National Science Foundation has called for a new, holistic framework of research to understand social and ecological interactions as a single coupled system focusing on the reflexivity between humans and nature. Social-ecological systems are complex and adaptive. They involve a great number of simultaneous interacting sub-systems and parts that evolve, manifest aggregate behavior, have the ability to anticipate and adapt, and possess no single governing rule (Holland, 1992).

In its 2009 paper submitted to the National Science Foundation, the Advisory Committee for Environmental Research and Education (NSF, 2009) advocates the following as a path to building knowledge and solving our global environmental problems—in a more pragmatic way:

If we are to understand and predict the consequences of ... wholesale alteration of ecosystems, a framework different from the traditional approach offered by physical and natural science disciplines is needed. Efforts to advance our understanding of complex environmental problems require studying ecological and social systems holistically as a single coupled system. A research framework for enhanced collaboration ... should address the issues of scaling and of thresholds and tipping points critical to our understanding of the long-term effects of environmental change. To accomplish this will require fundamental advances in the theory of complex systems and in the qualitative and quantitative analyses of complex system behavior. We must increase our ability to study how processes and outcomes connect across a broad range of spatial scales—from local to regional to global and of human dimension from individual to collectives. We also need to explore the role of contingencies in shaping dynamics of coupled nature-human systems to clarify the degree to which past outcomes of certain processes will be repeated in the future (p. 23).

...it is impossible to explore complexity without the capability of advanced computing to open a world of simulation exploring the non-linear relationships inherent in complex environmental systems...This informs and enables the decision support and adaptive management potential for policy makers (p. 16)...While the social and natural sciences have historically influenced each other, their joint application to environmental challenges remains limited given their different epistemologies and foci (p. 14).

A key motivating factor driving my interest to study aspects of a social-ecological system was the desire to learn and discover in new ways. As will be explored in Chapter 3, applying a collaborative mixed method approach was intentional from the outset. What I did not expect was the overall result and outcome that evolved and morphed through the exploratory process. The field site for this research was in a rural country setting of northern Arizona on the Navajo Nation in Burntwater of the Houck Chapter. However, the scope and aim of the collaborative and participatory approach used in my research was, even at the outset, intended to have a broader appeal and application in a wide variety of demographic and topographic contextual combinations and variations. It is my

hope that others might be inspired to explore further this collaborative combination approach or perhaps a variation thereof to address the pressing issues of complexity and adaptation in social-ecological systems in search of holistic and sustainable solutions to humanity's great environmental challenges of the 21st century.

RESEARCH QUESTIONS

My research is both empirically and theoretically driven. Empirically it draws on field interaction with the rural community of Burntwater, Arizona of the Houck Chapter on the Navajo Nation undertaken through a Navajo Nation Human Research Review Board approved study entitled *A Community Participatory Exploration of the Environment, Renewable Energy, Human Capacity Building and Entrepreneurial Solutions as Seen by the Navajo through Photo, Art and Stories* (NNR-10.282). Theoretically it draws on aspects of a resilience framework. Through a synthesis of learnings from both of these perspectives, I explore the following three questions in this Dissertation:

Q1 – How can a participatory research process using photovoice, artvoice and applications of the *Participatory Social Framework of Action - Collaborative Adaptive Capacity Building* (PSFA-CACB) conceptual model create individual awareness to bring about collective change and sustainable action to improve the environment and address local energy needs?

Q2 – What can an agent-based simulation model on cooperative behavior, *Taking Care of the Land – Human Environment Interactions* (TCL-HEI), tell us about the dynamic relationships between individual and collective awareness to bring about sustainable cooperative action and change regarding illegal trash dumping – an issue that was adopted by participants in the local community and explored through photovoice, artvoice and the PSFA-CACB conceptual model?

Q3 – What might a theoretical *Regional Cooperative Clean-Energy Economy* (RCCEE) look like through the lens of the TCL-HEI agent-based model depicting a clean-tech waste-to-fuels process as a sustainable entrepreneurial solution to create energy and jobs, and what are some likely positive and negative consequences for the regional environment and economy?

Results and learnings from the above three questions are then synthesized into a discussion around the following two questions:

Q4 - How has *collaborative adaptive capacity building* as a participatory process using photovoice and artvoice brought about positive change through sustainable social action and how is this in turn building resilience to withstand disturbance and overcome vulnerability through collective cooperation and unity in action?

Q5 – How has this tri-phase dual-model (PSFA-CACB conceptual model; TCL-HEI agent-based model) collaborative research added value to problem solving in complex adaptive social-ecological systems?

RESEARCH OVERVIEW

Due to the complexities and nonlinearities in social-ecological field research and the desire to apply a more holistic method, I adopted a *semi-collaborative social research* approach. Collaborative social research involves collective research action taken in a social setting where accompaniment between the researcher and those being researched remains reflexive (Miles et al., 1994). In this context, both parties are involved in the design process and implementation process and where the data is shared with the *activists* as feedback to help construct and implement the next phase of the research (Whyte, 1991). My approach was *semi-collaborative* in that I needed to outline the framework of my research design and implementation for pre-approval from both the University and

Navajo Nation Internal Review Boards prior to being able to conduct research involving people.

Using a collaborative social research method to acquire qualitative data coupled with conceptual and simulation model analysis, my overall study objective was to evaluate collaborative adaptive capacity building in a resilience framework. I did this with the use of a conceptual model to inspire collaboration along with an agent-based simulation model. I designed this mixed model approach to evolve over three distinct phases where the results from one phase would feed into the next. Phase-I involved an exploration of local viewpoints on community environmental and local energy issues using qualitative exploratory interviews, and photovoice and artvoice techniques that established a general understanding and awareness of the exploration and resulted in a community-identified issue of concern—illegal trash dumping. Phase-II focused on the central community concern of illegal trash dumping through a series of weekly community gatherings where I introduced a model framework called Participatory Social Framework of Action (PSFA). Central to the PSFA model is the concept of Collaborative Adaptive Capacity Building (CACB) that I introduced as a working model to the participants and which became the core focus. It was during the first 18 months of my doctoral work that I developed the PSFA-CACB model construct with the intention of being able to use it in the field. A key feature of the CACB component of the overall model is a reflexive and iterative cycle of reflection, consultation, action, accompaniment, learning and adjustment. Phase-III then focused on using the data gathered from Phase I and Phase II to inform a two-tiered agent-based simulation model. Taking Care of the Land – Human Environment Interactions (TCL-HEI) is an agent-

based model dealing with human-environment interaction (HEI). Tier-I of TCL-HEI, focuses on cooperative behavior, capacity building and decision making dynamics. Tier-II of TCL-HEI looks at aspects of a Regional Cooperative Clean-Energy Economy (RCCE) and is theoretical, depicting a hypothetical clean-tech waste-to-fuels program for the Navajo Nation. Combined, TCL-HEI (Tier-I & II) is a semi-hypothetical model used to evaluate theoretical implications such a clean-technology waste-to-fuels program might have on the regional economy and environment.

In addition to any collaborative and capacity building benefits derived from the research process, there has been an increased awareness of environmental concerns regarding illegal trash dumping that has galvanized into real community action with boots on the ground involvement inspired by local leadership. Further potential benefits that remain to be seen might be Navajo Nation Chapters adopting the PSFA-CACB conceptual model to identify and resolve other local issues; policy makers using the TCL-HEI simulation model to inform decision making regarding behavioral actions on illegal trash dumping, cleaning the environment, and waste-to-fuels and recycling opportunities in creating a *Regional Cooperative Clean-Energy Economy*. The overall hope is that community leaders might seek funding to evaluate a potential Navajo Nation waste-to-fuels clean-energy pilot program.

DISSERTATION CHAPTERS

I have written my research in five dissertation chapters: 1) introduction, 2) background, 3) results for a conceptual model, 4) results for an agent-based model, and 5)

synthesis of fieldwork and theory. I provide a summary of chapters 2, 3, 4, and 5 in this section.

SUMMARY - CHAPTER 2
BACKGROUND: A THEORETICAL AND METHODOLOGICAL
FRAMEWORK FOR UNDERSTANDING SOCIAL-ECOLOGICAL SYSTEMS

This chapter sets up a theoretical and methodological framework in which the complexity of social-ecological systems might better be understood. A key understanding underpinning this framework is my perception of reality: *social reality* in relation to *physical reality*. In the context of my research, social reality pertains to that which is fabricated and conceptualized by humanity while physical reality constitutes the natural geo-bio-chemical world. While social reality is dependent upon physical reality, they are dynamic, mutable, ever changing and reflexive to each other. A key distinction is that humans, as rational beings, have the ability consciously to change their environment for better or worse. What is yet undetermined is what degree of resiliency is built into the current social-ecological system allowing for change and disturbance to occur while still being able to revert back to some semblance of its original state. If humanity changes the natural environment, too drastically or too swiftly will this create unintended disturbances and shocks? Could such disturbance push our social-ecological system to a threshold, a tipping point, beyond which the system would be so transformed with never before seen changes at all scales (temporal and spatial)? Equally important, should such a system transformation take place, will humanity then have the capacity to adapt to a new way of life? Adaptive capacity is a key tenet of the resilience framework within which my research is interwoven. Chapter 2 explores this framework along with what I consider to

be a more holistic perspective on discovery and knowing as called for by the National Science Foundation (NSF, 2009) in search of viable and sustainable solutions to our global issues stemming from social-ecological interactions. I take an approach that aims to avoid the intractable debate between positivism and relativism by introducing the concept of hermeneutics and the practice of collaborative consultation and reflection in search of pragmatic truth based on collective opinion. It is in this chapter that I discuss more fully the conceptual model: *Participatory Social Framework of Action* (PSFA) along with its inner core *Collaborative Adaptive Capacity Building* (CACB). In this conceptual framework are key social interacting forces of human nature such as service, accompaniment with others, reflection, collaborative consultation, and learning in action. I take the position that these forces can significantly impact positive decision making and a strengthening in individual, institutional and community capacity building that act as positive feedback to *the system* propelling it forward on a positive trajectory and a more sustainable path.

SUMMARY - CHAPTER 3 RESEARCH METHODS AND RESULTS: PHOTOVOICE, ARTVOICE, AND THE PSFA-CACB MODEL

This chapter reviews the core of the exploratory field research that took place over the course of nearly two years of frequent and sometimes irregular site visits. I designed the study around a tri-phase plan of action. Phase-I was officially launched in the late summer of 2010 after having received the go ahead from the Houck Chapter and the Navajo Nation Internal Review Board. Making initial contact and establishing me in the field was not an easy task as I am sure is the case for most novice field researchers.

By design, I chose to use an exploratory interview and focus group questioning method as a way to introduce myself and for the participants to introduce themselves to me. It worked well as an initial step into Phase-I. I then followed through with several attempts to launch a community gathering to share the overall scope of the project and to generate an interest. Once there was sufficient interest it was possible to begin the photovoice and artvoice distribution and from that point forward matters began to take on a different form with a new level of energy. The core result of Phase-I was a community-led identification of a real and local social-ecological problem—illegal trash dumping. Phase-I was concluded with a successful community gathering that held great promise for a launch into Phase-II to begin exploring this community-adopted issue using a conceptual model approach on *collaborative adaptive capacity building* as set within a *participatory social framework of action*. The iterative and reflexive process of working in the field with action, learning, adjusting, reflecting and consulting was carried on during Phase-II but as one can imagine, it was not always in a textbook manner as learning the technique of the CACB model was very much a *collaborative adaptive capacity building* exercise in and of itself. A measure of the success of Phase-II was the 2010 summer culmination of a community self-organized initiative to clean up the environment that drew attention across the Navajo Nation. The information and data from both phases I and II were then used to inform and parameterize an agent-based model during Phase-III for analysis and discovery. The results for this are provided in Chapter 4.

SUMMARY- CHAPTER 4

RESEARCH METHODS AND RESULTS: *TAKING CARE OF THE LAND – HUMAN-ENVIRONMENT INTERACTIONS* -- A TWO-TIER AGENT-BASED MODEL

Chapter 4 looks at the research results of the final exploration phase, Phase-III, that focused on developing the agent-based model *Taking Care of the Land-Human Environment Interactions* (TCL-HEI) which hypothetically models certain aspects of the field study conducted during Phases I and II. The TCL-HEI model is split into two tiers. Tier-I is foundational and deals with key aspects of the social-ecological interplay between the environment and three types of participants. Tier-II builds upon Tier-I where I present a new layer of complexity with the introduction of key economic variables and discusses a theoretical conceptual model pertaining to a *Regional Cooperative Clean-Energy Economy* (RCCEE). Overall, the synthesis of TCL-HEI (Tier I & II) with RCCEE represents a semi-empirical and theoretical sustainable entrepreneurial solution to addressing the issue of illegal trash dumping that emerged during the Phase-I exploration using photovoice and artvoice. With assistance from administrators, officials and policy makers at the Chapter, Agency and National levels on the Navajo Nation such a novel solution might find its way forward as a more holistic and pragmatic approach to understanding better the complexities of social-ecological systems on the Navajo Nation that deal with solid waste and the environment.

SUMMARY - CHAPTER 5
CONCLUSION: SYNTHESIZING AN UNDERSTANDING OF
COLLABORATIVE ADAPTIVE CAPACITY BUILDING WITHIN A
RESILIENCE FRAMEWORK

Chapter 5 presents a review of my research methods and results that are then interwoven with the concepts of resiliency, adaptive capacity and sustainability to arrive at an understanding of *collaborative adaptive capacity building* within a resilience framework and how my collaborative tri-phase dual-model research has added value to problem-solving an issue in a complex adaptive social-ecological system. In essence, this chapter brings my entire research together by synthesizing an understanding of the conceptual model *Participatory Social Framework of Action – Collaborative Adaptive Capacity Building* (PSFA-CACB) along with the results of the agent-based model *Taking Care of the Land – Human Environment Interactions* (TCL-HEI) within a resilience framework.

I show that under current conditions the area of my field site (the system) rests in an undesirable regime basin attraction due, in part, to prevailing economic forces such as long driving distances, high fuel costs and trash dumping tipping fees and that this may in part be driving human behavior to dump trash illegally and causing environmental degradation. Using results from Chapter 4 I then show that with a change in state variables of the stability landscape of the social-ecological system, such behavior can be changed. The hypothetical scenario presented to effect such change is a sustainable entrepreneurial business cooperative that generates revenue from recycling and converting solid waste to clean-energy through a theoretical waste-to-fuels process facility. In doing so, sufficient incentive is introduced to change behaviors. In the resilience framework context these positive forces are overcoming the inertia of the old

landscape configuration that had been keeping the system locked into its undesirable state and not allowing for a regime shift into a new basin of attraction—there is potential for a new social reality to emerge.

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endnote

¹ The term was coined by ecologist Eugene Stoermer and popularized by the Nobel Prize-winning atmospheric chemist Paul Crutzen.

CHAPTER 2

CHAPTER 2

BACKGROUND: A THEORETICAL AND METHODOLOGICAL FRAMEWORK FOR UNDERSTANDING SOCIAL-ECOLOGICAL SYSTEMS

INTRODUCTION

This chapter sets up a framework in which the complexity of social-ecological systems might better be understood. At the outset, a key concept underpinning this framework is that of reality: *social reality* in relation to *physical reality*. From the perspective I have taken here, social reality pertains to that which is fabricated and conceptualized by humanity. This is in comparison to physical reality, which constitutes the natural geo-bio-chemical world.

Social reality is dependent upon physical reality and both are dynamic, changing, and mutable. However, unlike the natural world which is subject to and confined within the laws of nature, humans are an exception to the rule. Although comprised of elements and constituent parts derived from physical reality, like other animals, we humans have the ability to rationalize and reason giving us an ability to be free from these restrictions. Over the ages we have exhibited the capacity, knowledge and power to consciously change our social reality, resulting in negative and positive outcomes. It is these outcomes that impact complex social-ecological systems at varied temporal and spatial scales.

It is upon this foundational understanding of reality that I place a framework of resilience thinking to understand change within the social-ecological system. Adaptive capacity within a resilience framework is the capacity to adapt and shape change

(Resilience Alliance, 2002; F. Berkes et al., 1998) and is a key concept, along with resilience, adaptation, sustainability, and collaboration that are explored in this chapter.

In the spirit of *adaptive capacity* and as called for by the NSF (2009), humanity needs to adapt by developing new strategies to tackle complex anthropogenic issues impacting the global environment. To explore *a new way forward*, adopting a *holistic* perspective and strategy in search of viable and sustainable solutions to our global issues stemming from social-ecological interactions, humanity and in particular the community of thinkers, researchers and policy makers, might do well to consider different approaches and understandings to *paradigmatic* concepts of knowledge, truth, reality, and methods to research and learning.

This chapter attempts to shed light in this area by exploring a framework upon which this thesis and corresponding research is based. To this end, given the vast spectrum of human thought ranging from the extremes of positivism to relativism in this postmodern era, it is not only beneficial but necessary to establish a foundational research framework. Miles and Huberman (1994, p. 4) makes this point:

It is good medicine...for researchers to make their preferences clear. To know how a researcher construes the shape of the social world and aims to give us a credible account of it is to know our conversational partner. If a critical realist, a critical theorist and a social phenomenologist are competing for our attention, we need to know where each is coming from. Each will have diverse views of what is real, what can be known, and how these social facts can be faithfully rendered.

The ontological framework around which this thesis is constructed is based upon an integrated understanding of truth and knowledge in the context of a broader realization of social and physical reality within which to discuss the complexity of social-ecological systems and corresponding essential characteristics of resiliency, adaptive capacity,

collaboration and sustainability. It stems neither from a positivist nor relativist epistemology but rests upon what I would view to be a more moderate and relevant foundation based on hermeneutics. This chapter will conclude with a synthesis of these varying concepts into a coherent framework that may shed light upon humanity's pursuit of sustainable solutions to its complex and sensitive relationship with the natural world.

REALITY, KNOWLEDGE, AND TRUTH

REALITY

The general concept of reality I have adopted here is in line with Searle (1995) as elucidated by Lample (2009). Searle begins by identifying aspects of reality as existing in and of themselves outside of any human opinion. These he calls reality of *brute facts*, which comprise the world of nature and our physical universe. This is what I have thus far referred to as *physical reality*. Then there are the phenomena in the world which exist due to human interaction and which are based on *institutional fact* (Searle, 1995) or which require the involvement of human institutions to bring them into being. For example, a wood table, a car, or a five dollar bill—all of which involve to a certain degree of language, law, organization, governance, etc. to bring them into being. This is what I have so far referred to as *social reality*. Social reality must ultimately emerge from the canvas of physical reality and it is here that humanity finds the complex interweaving of social-ecological systems. To explore in depth the complexities of social reality falls outside of the scope of my research. However, emphasis should be made to differentiate this framework so as not to be perceived as being *relativistic*. As pointed out by Lample (2009), Searle's approach is not relativistic in that the construction of social reality is

based upon an objective physical reality obtained through external realism using the truth-method of correspondence (empiricism) in comparison to other methods of truth verification such as coherence-truth and pragmatic-truth (Edick-II, 2011)¹.

KNOWLEDGE and TRUTH

The concepts of ‘knowledge’, of ‘knowing’, of an epistemology, are at the core of a protracted debate between modernism and postmodernism advocates. As perceived by Lample (2009, p. 162) “In undermining the authority previously granted to foundational truths of science and universal values, it [postmodernism] appears to have opened the door to endless, adversarial criticism and struggle for power among rival relativistic perspectives.”

In the field of qualitative research, the issues of reliability/validity or trustworthiness have been explored through a number of lenses with varying positions—see for example Glaser, 1978; Guba et al., 2005; Lincoln, 1985; Seale, 1999. Some researchers see this matter of reliability and validity through a more positivistic perspective. Other researchers may take a more constructivist point of view where “objective knowledge of the world is impossible, since all observation is driven by pre-existing theories or values that determine both how objects are constituted in sense experience and why some objects are selected rather than others” (Seale, 1999, p. 23). Seale further describes abduction, retroduction and qualitative induction as alternative approaches to a conceptual middle ground between deduction and induction. This recent discourse over what is an appropriate qualitative method has been ongoing for several decades and can be said to revolve around differing opinions stemming from this sea of

paradigms and shifting periods. They involve value concerns (axiology), issues over control and power regarding process and outcomes, validity and foundational relationships to truth and knowledge, the voice of the author and research subjects, textual representations and ontological concerns about paradigmatic commensurability (Guba et al., 2005). I find myself agreeing with Miles and Huberman (1994) and Howe (1988) as they place themselves in that camp of researchers who are too wary of meaningless epistemological debates which have little to no bearing to practical research in pursuit of knowledge. In the happy pursuit of not finding a place squarely in one of these *paradigmatic* ontological rooms I began to realize that perhaps my approach might best be described as being *epistemologically collaborative*. The position I have come to adopt in this dissertation is one of neither extreme (positivistic-fundamentalism or relativistic-liberalism) but rather what I would consider a moderate, balanced and therefore more constructive approach. Ontologically, in the world of qualitative research perhaps the best description of my approach would be what Miles and Huberman (1994, p. 8) describe to be “collaborative social research” compared to two other broad categories of qualitative data analysis they identify such as interpretivism and social anthropology. Interpretivism is a line of inquiry set upon the premise that natural and physical science methods are inappropriate at analyzing social phenomena (human discourse and action); whereas social anthropology uses a variety of methods including ethnography as perhaps being the most established. The multiple-methods approach I have deployed in my research places my work in the collaborative social research category as defined by these authors where collective action takes place in a social setting exhibiting accompaniment and interaction between the researcher and the participants.

Based on the authors' descriptions there are overlapping similarities between all three domains. Take for example social anthropology and collaborative social research, there are similarities involving fieldwork, observation, and applications of critical inquiry. A key distinction between the two is at the participatory level. Collaborative social research is highly participatory at various stages throughout the process where accompaniment is expressed through reflexivity or dialectic deliberations to arrive at a common knowledge. But there are also similarities between collaborative action research and naturalistic studies, a field within the domain of interpretivism. Commonalities between the two include "participant observation, sensitivity to participants' concerns, focus on descriptive data in the initial phases, non-standardized instrumentation, a holistic perspective, and the search for underlying themes or patterns" (Miles, et al., 1994, p. 9). A key feature of collaborative social research is the collaboration and participants involved at the outset with experiment design, data collection and reflection on the data as feedback. This iterative method has been around in varying forms since the 1920s, albeit known by different names such as *participatory action research* (Whyte, 1991).

However, I have not based my research framework on the notion that knowledge is just a fabrication of social construction as many constructivist and relativist might claim. On this point and in favor of a holistic approach to knowledge building (discussed below), Medina (2006, p. 405) states "contrary to constructivist theoretical dogma, absolute Truth does exist, and all types of methods and techniques should be used when seeking this Truth."

A key factor regarding trustworthiness in qualitative research is establishing a solid track record of accountability where audiences will come to know and trust

reliability in the outcomes. Due to the nature of my research as a participatory collaborative engagement utilizing qualitative data, I have partially stepped out of the classical western-science paradigm where results are typically validated using measures of internal and external validity, reliability and objectivity that fit reasonably well with quantitative data. To offset the quantitative measure with qualitative ones, Lincoln discusses credibility, transferability, dependability and conformability (Lincoln, 1985, p. 300). I discuss these in Chapter 3.

In this chapter I support the position that the acquisition of knowledge in search of truth is not fixed upon a solid inflexible foundation but is *non-foundational*, much like that of a solid but drifting raft upon which incremental change in knowledge can occur (Lample, 2009; Sosa, 2000). As such, Lample (2009) expresses knowledge in a non-foundational framework as not something to be possessed and put away as if to represent some perfect set of facts reflecting what true reality might be, nor is knowledge seen to take the position that all views are equal or all ways of knowing equally valid as seen through a relativistic lens. Rather, knowledge is seen as an ever evolving collective of the human intellect tied to language, inter-subjective verifiability, justification, relations of power, universal norms and theory which are attuned to reality but subject to change as they reach their limitations. Lample states:

The human enterprise is, then, the never ending investigation of reality, the search for truth, the quest for knowledge, and as important, the application of knowledge to achieve progress, the betterment of the world, and the prosperity of its peoples...[it] portrays human beings as investigators of reality, seeking to interpret and understand the world, and then acting on that understanding to achieve the consensus that shapes social reality (Lample, 2009, pp. 172-173).

This way of an open and non-linear approach to knowledge building is very much in line with the field of systems dynamics and simulation modeling which is a foundational method used in my research. Marjan van den Belt (2004, p. 6) stresses this issue about knowledge building:

Academia has traditionally embraced a logical positivist perspective based on Greek ideal for understanding the world. These ideas still strongly influence the modern course of science. The logical positivist philosophy asserts that one *right* answer exists. In this view, the *right* answer will emerge if one keeps looking in increasing detail and scientists are meant to be the objective unbiased searchers for this answer. Outcomes: 1) compartmentalization of science that has produced many disciplines and well guarded, hard to cross disciplinary boundaries; 2) in today's educational system people are trained predominantly in analysis – the art of taking problems apart to study the parts in ever-increasing detail. Very little attention is given to synthesis – the art of putting the pieces back together into a well functioning apparatus... Research needs to be adaptive if it is to benefit adaptive managers and support policy makers in becoming more responsive.

Humanity's attempts over the ages to seek out truth have yielded a cycle between objectivism and relativism. This is much like the swinging of a pendulum where a secure foundation for knowledge is established for a period until its weaknesses are exposed placing that foundation in doubt and giving rise to an era of relativism until the next foundation of truth emerges. As Bernstein (1983, p. 9) puts it, "Each time that an objectivist has come up with what he or she takes to be a firm foundation, an ontological grounding, a fixed categorical scheme, someone else has challenged such claims and has argued that what is supposed to be fixed, eternal, ultimate, necessary or indubitable is open to doubt and questioning". Objectivism, as pointed out by Lample (2009), holds that knowledge must be grounded on a particular basis. Lample quoting Bernstein (1983, p. 8) states that objectivism is "the basic conviction that there is or must be some permanent, a-

historical matrix or framework to which we can ultimately appeal in determining the nature of rationality, knowledge, truth, reality, goodness, or rightness". History has shown that knowledge claims made on behalf of any particular foundation have ultimately failed to hold true, giving rise to relativism. In contrast, relativism can be seen as holding to "the view that any claim to truth, knowledge or morality are not absolute but exist only in relation to a particular culture, society, or historical context ... and the values and beliefs of one cannot be judged by the standards of another" (Lample, 2009, pp. 170-171).

A significant factor that has contributed to the protracted debate between the extremes of objectivism and relativism is the notion of paradigms. The modern use of the word paradigm refers to a thought pattern in scientific disciplines and epistemic contexts in a given period. This contemporary meaning is attributed to Thomas Kuhn (1996). Kuhn explains that for there to be a paradigm shift, a number of phases are traversed where the existing paradigm encounters an anomaly (something that can't be denied nor explained) that is ignored or rejected by the establishment within the paradigm. Then attempts are made to try to explain this anomaly within the context of the current paradigm and eventually a new paradigm may appear where the anomaly is resolved but ridiculed and rejected by the old paradigm and eventually the new paradigm is accepted. From a Kuhnian paradigmatic perspective, most paradigm shifts need time to work themselves out and as such he sees the concept of "paradigm" as being contextually inappropriate in social science due to the fluidity of knowledge and concepts moving back and forth from the contemporary to the historical and the proliferation of schools of thought (Kuhn, 1996). Another criticism of paradigmatic epistemology is that it runs

counter to scientific objectivity when set in a society of *normative adversarialism* where there is a “tendency to assume that contests are normal and necessary models of social interaction” (Karlberg, 2004, p. xv). This can perhaps be seen by the establishers of a successful paradigm having a vested interest both intellectually (ego/reputation) and economically (research funds) to *play the game* for as long as it can be reasonably played, arguably, is not conducive to good objective science. In this context, Karlberg (2004) emphasizes that the foundation of this normative adversarialism stems from a western-philosophy based and hierarchical linked tripartite system of economics, law and politics over a struggle for increased power that has given and continues to give rise to a *culture of contest*.²

Clive Seale (1999, p. 8) makes a pragmatic suggestion to qualitative researchers in the same spirit of the above argument for non-adversarialism: “Rather than opting for the criteria promoted by one variety, ‘paradigm’, ‘moment’ or school within qualitative research, practicing researchers can learn valuable lessons from each one.” To be outside a given paradigm, i.e., not having to defend it, allows one to be more objective in the pursuit of truth that is more in keeping with a classical notion of science. I believe a key point being made here is that there are other ways of moving forward within a discourse; that it does not have to be adversarial, including in our halls of academia that shape contemporary scholarship referred to as the “adversary paradigm” (Moulton, 1983). However, a rethinking of the traditional models of *power* from *power to* such as ‘my power to conquer’ and *power over* such as ‘my power over you’ to a model of *power as capacity* (Karlberg, 2004, p. 30) might better enable individuals to see *power* as a means to make choices to either compete or cooperate. This might then open an alternative

pathway away from competition and adversarialism towards cooperation and mutualism—a coming together.

While it is true that science analyzes, is it not also true that science integrates and seeks out underlying patterns of cohesion and oneness? This is the foundational framework upon which my research is based and there is a growing discourse that supports this view. Haleh Arbab (2000, pp. 1-2)³ in a paper presented at the Colloquium on Science, Religion and Development in New Delhi referenced the philosopher and physicist David Bohm:

...the way most intellectual disciplines treat theory today is intimately connected with the fragmentation of thought that is prevalent in society. At the most fundamental level, this fragmentation arises, he argues, from our insistence that our theories correspond to “reality as it is” rather than being manageable models of limited sets of phenomena occurring within an objective reality that is infinitely complex. Since our theories are necessarily fragmented, by considering them replicas of “reality as it is,” we end up assuming that reality itself is fragmented. And so we miss the interconnectedness of all things...

This is what systems theory looks at with whole systems, the *interconnectedness of things* within a given system under evaluation. Arbab (2000) goes on in her talk bringing light to how we might rethink a utilization of fragmented theories as sources of insight and how this has helped the FUNDAEC (Foundation for the Application and Teaching of the Sciences) program in Columbia structure meaningful lines of action (F. Arbab et al., 1988). The theoretical and methodological approach taken in my research regarding iterative cycles of collaborative consultation and reflection; action and implementation; learning and adjusting as a means to building capacity have conceptual underpinnings coming from the FUNDAEC initiatives that date back to the 1970s.

The FUNDAEC program takes an approach regarding the practice of action, reflection on action, research, and study with a focus on change. Working within an evolving conceptual framework enables a working integration between theory and practice and enables resulting social action to be consistent and coherent (H. Arbab, 2000). In this context, there is an element of truth validation as the iterative cycles act as a system of checks and balances, grounding theory and constructs and allowing for place-based social action to be reevaluated in the light of newly emerging concepts and theories. Also, being collaborative at multiple scales and spanning boundaries enables the process to remain open for qualitative research validation techniques such as member validation, peer briefings and triangulation. This is a process of learning in action or as the National Research Council puts it “integrating knowledge in action” where they state, “Because the pathway to sustainability cannot be charted in advance it will have to be navigated through trial and error and conscious experimentation. The urgent need is to design strategies and institutions that can better integrate incomplete knowledge with experimental action into programs of adaptive management and social learning” (NRC, 1999, p. 10).

Another key facet to the overarching framework being established in this chapter is discovery through pragmatic-truth based on reason and social discourse. This notion dates back to Aristotle with his description of practical reasoning (*phronesis*) where “the action of a community is guided and directed by *phronesis*, that involves reasoning through dialogue, an exchange of differing opinions, interpretation, judgment, and decision-making. It includes practical application of principles to particular situations—a kind of ethical know-how... When consensus in a community breaks down ... then this

type of practical discourse is needed to re-establish the collective agreement upon which further action depends” (Lample, 2009, p. 172). It is upon this Aristotelian foundation that pragmatism can yield to a discovery of pragmatic-truth derived from the usefulness of an idea so long as there is no contradiction with coherence-truth (when an idea coheres logically with an established set of beliefs, i.e. rationalism) or correspondence-truth (when an idea positively corresponds to facts such as empiricism through observation).

The framework I have adopted presents a knowledge-base through hermeneutics rather than epistemology and in so doing manages to steer clear of the clash between modernism and postmodernism, objectivism and relativism. Hermeneutics deals with a set of “principles of interpretation used to unravel communication and human understanding” (Lample, 2009, p. 172). This in essence opens a door to fact finding and knowledge building that can be more holistic in approach, allowing for a collaboration of quantitative and qualitative approaches as called for by the NSF—to finding solutions to the anthropogenic problems stemming from our complex social-ecological systems. The holistic approach allows for the inclusion of important human dynamics such as traditional knowledge and belief systems that so often rely on metaphysical explanations and as such are excluded from the classical *Cartesian-Newtonian* worldview but that are nonetheless a real and valid part of human experience and understanding. The Cartesian-Newtonian worldview as described by Medina (2006, p. 6) is:

... named after the famous European scientists René Descartes and Isaac Newton. Unfortunately, this classical science worldview is based on a mechanistic view of human beings and the universe that alienates human beings from their spiritual, moral, and emotional faculties. It has divided the world into mutually exclusive opposing forces: the dichotomies of science versus religion, reason versus faith, logic versus intuition, natural versus supernatural, material versus spiritual, and secular versus sacred. The result is a materialistic worldview that emphasizes the truth of

science, reason, logic, the natural, the material, and the secular while ignoring or even denigrating the truth of religion, faith, intuition, the supernatural, the spiritual, and the sacred.

In contrast, I have striven towards laying a research foundation that allows for a conception of reality that advocates a more holistic framework (Capra, 1982; Medina, 2006) through an exploration using techniques of artvoice, photovoice and a reflexive interaction of consultation, accompaniment in action, learning and reflection that is open to all opinions and values. Through such a collaborative technique where “simultaneous efforts ... to consult, and to learn in united action, diverse points of view are harmonized to contribute to the discovery of truth ... individuals are not asked to compromise their beliefs [but they] have to learn to avoid conflict and contention, reassured that problems will be resolved over time” (Lample, 2009, p. 184). It is through an appreciation and understanding of the “law of the whole” as described by Physicist David Peat that we might have a different perspective of our world and its problems. This burgeoning holistic educational philosophy is consistent with many of the latest discoveries in quantum physics and is in line with many traditional native belief systems depicting a sense of unity and oneness in all of reality (Medina, 2006; Peat, 2002).

From the perspective of the framework being established here, an essential aspect of building truth and knowledge through means of a holistic approach involving collaborative and participatory endeavors revolves around the inclusiveness and unity of the effort. Within this framework is the concept of *consultation* that has proven to be understood differently within various circles of collaborative thinkers and often perceived as a less-than valued method of deliberation. For example, Daniels and Walker (2001, p. 71) make a comparison between consultation, consensus and collaboration where they

refer to consultation as “activities that involve parties in the ... decision process without sharing any aspect of the decision itself. It is a legitimate and viable decision-making strategy, but it is not collaborative. Its basic activities are information gathering and feedback.” To be clear, this is not the type of consultation that is being used in this study. Consultation can be non-collaborative if it is intended to be used in the context of Daniels and Walker. However, in the context of this study, the notion of consultation and collaboration go hand-in-hand. This can in part be expressed and understood through the lens of the Baha’i Faith where it has been practiced globally in a wide and varied number of urban and rural settings for over a hundred years and can be considered a tested social tool of effective collaborative engagement and decision making. Drawing on excerpts from the Baha’i Writings, Lample summarizes this particular understanding of the concept of consultation as being guided by a number of clearly expressed principles, stating:

Speech can exert a powerful and lasting influence for good or ill, therefore, it must be exercised with wisdom. Individuals are free to put forward their views and should not be offended by the views of others. Opinions are presented without passion or rancor; conflict and contention are strictly forbidden, and, if they arise, discussion should cease until unity is restored. The clash of differing opinions brings forth the spark of truth, and all are to listen for the truth as differing opinions are shared, for reality lies where opinions coincide. For this reason, to stubbornly cling to one’s opinion is to ensure that the truth will remain hidden; it will inevitably lead to discord...Above all, the foundation of consultation is love and fellowship (Lample, 2009, p. 25).

A process that seeks the widest possible variation of opinions in an atmosphere of cooperation and trust with a goal of seeking truth is far more likely to discover a deeper sense of reality based on coinciding opinions. In practice this can be a very challenging goal due to varying degrees of human maturity, egos, attitudes and the like but

nonetheless it is a goal worth striving for. In circumstances where the representation is limited or skewed respective to the surrounding population or for that matter where disunity is encountered even with excellent representation the outcomes may not reflect the reality of truth due to bias, non-inclusivity or discordance of opinion. In a research context, to deliberately block or prevent voices from being heard would be a form of deception of the results and deception should be thought of as nothing less than lying, which is the opposite of searching for truth. Further to the above correlation with consultation as a means of seeking truth, the Baha'i teachings say this about lying:

Consider that the worst of qualities and most odious of attributes, that is the foundation of all evil, is lying. No worse or more blameworthy quality than this can be imagined to exist; it is the destroyer of all human perfections and the cause of innumerable vices. There is no worse characteristic than this; it is the foundation of all evils. (Abdu'l-Baha, 1930, pp. 214-216)

Truthfulness is a foundational principal in most morally-based societies including many traditional ways such as with the Navajo where the Coyote emerges from the Navajo Creation Story as the archetypical trouble maker (Locke, 2001a) representing the “trickster” who mixed his “non-being and lies into the Great Spirit’s creation of the world (Edick-II, 2010, p. 105). Tom Torlino (Fig. 2.1) was a holy man of the 19th century Navajo subjected to western style boarding schools who spoke of truth.

The traditional Navajo have no word in their language for religion and they do not see religion as something external to their being, a place to go, a thing to worship or a separate entity to be believed in or to which to subscribe (Locke, 2001a). To the Navajo and perhaps more so with traditional Navajo, religion is in their being, it is a way of life, it is ever present. Religion could “no more be separated from the traditional Navajo’s

daily life than eating, breathing, sleeping, or the ground he walks on that gives him substance, the sun that gives him warmth, or the summer lightning that gives him fear” (Locke, 2001a, p. 45). From a different perspective, regarding the expression of values,



“Why should I lie to you? I am ashamed before the earth ; I am ashamed before the heavens ; I am ashamed before the dawn ; I am ashamed before the evening twilight ; I am ashamed before the blue sky ; I am ashamed before the darkness ; I am ashamed before the sun ; I am ashamed before that standing within me that speaks with me. Some of these things are always looking at me. I am never out of sight. Therefore I must tell the truth. That is why I always tell the truth. I hold my word tight to my breast” (Philip, 1997, p. 82)

Fig. 2.1 Tom Torlino, Diné

Kluckhohn and Leighton (1974) focus on the difference in the way the Navajo *make virtues* such as truth and honesty. To the Navajo, there is no “appeal to abstract morality or to adherence to divine principles” (Kluckhohn, et al., 1974, p. 297). These would include expressions of positive behavior, generosity, self-control and an affectionate duty to relatives, acting as if everybody was one’s own relatives. Further, the Navajo were observed to have a courteous, nonaggressive approach to others. This was seen as the essence of decency. Polite phrases to strangers such as speaking approvingly of someone might yield a phrase such as “he talks pretty nice” (Kluckhohn, et al., 1974, p. 299). Health and strength are highly valued and seen as perhaps the best of the good things as this enables work and a way to make a living for one’s family. Being industrious and productive are valued, particularly of the older generation. A good appearance is valued, among other things (Kluckhohn, et al., 1974).

Truth must be found not just by seeing (empiricism) but also by thinking (reason) (Edick-II, 2010) and it is through the exchange of opinions and ideas among people that awareness can be raised and thoughts elevated to arrive at a deeper sense of truth and reality; yet never quite fully knowing the full picture. Abram Moslow (1964, p. 54), cited in Medina (2006, p. 119), confirms this, stating “knowledge is not complete, ... Though it is relative to man’s powers and to his limits, it can yet come closer and closer to ‘The Truth’ that is not dependent on man.” While this begs a discussion on metaphysics that remains beyond the scope of this research it does leave open the door to ask the question: if a large portion of humanity continues to ignore the possibility of a metaphysical reality or refuses to inquire into the science of consciousness, are we not in a sense deceiving and lying to ourselves while hiding behind established paradigms yet ignoring anomalies that continue to challenge the foundation of these established views? If one is willing to explore the possibility of metaphysics and a higher consciousness then one might be willing and able to be more accepting of cultures and knowledge forms outside one’s own worldview. When this happens, a new realization sets in for the need to consider and explore indigenous belief systems including certain traditional religious beliefs that in certain areas is on a comeback and where “in Native American traditions all aspects of life take on religious significance and religion and culture are intimately connected” (Michaelson, 1983, p. 112). The Lakota Chief Luther Standing Bear depicts a corresponding relationship between The Great Spirit, humanity, and nature (Fig. 2.2).

Nature and the environment are an integral part of the Navajo, both physically and spiritually, shaping their social reality. Physical description in the Navajo language is very pronounced. Young and Morgan (1943) referred to it as an objective physical

description. This perhaps suggests why there is such a rich use of environmental description by the Navajo.



“From Wakan Tanka, the Great Spirit, there came a great unifying life force that flowed in and through all things – the flowers ... blowing winds, rocks, trees, birds, animals – and was the same force that had been breathed in the first man. Thus all things were kindred, and were brought together by the same Great Mystery. Kinship with all creatures of the earth, sky, and water was a real and active principle. ...All were of one blood, made by the same hand, and filled with the essence of the Great Mystery” (Medina, 2006, p. 209).

Fig. 2.2 Chief Luther Standing Bear, Lakota

Ecological references to the environment, both biotic and abiotic, are passed along from generation to generation through artistic expressions like the narrative of the Navajo Story of Creation, the creation of music through the Native American flute depicting elements of nature, to sand-paintings (properly known as “dry-paintings”) illustrating natural landscapes and indigenous symbolism (Locke, 2001a, 2001b).

From a traditional perspective, there are many Hopi and Navajo who, in the spirit of unity and collaboration and despite a checkered history of struggle between the two tribes, look beyond a divisive 1974 Congressional law commonly referred to as the *Relocation Act*⁴. This Act resettled thousands of Navajo and over a hundred Hopi, to see these lands as always having been shared between them. A report of traditional Hopi concerning coal-mining issues at Black Mesa perhaps depicts what many Navajo and Hopi value.

We want to meet with the Navajo Traditional and religious Headmen to work out a common stand against this bill that will again cut up our homeland and create more division. We want the Navajo Elders to sit down with us to look seriously into our Way of Life. Religion and Land in the light of our traditional and religious knowledge... As far as the Navajo people are concerned, it is our position that they be allowed to remain within the Hopi traditional land area ... the Navajo and Hopi people have lived side by side for generations and our roots are deep within the land on which we live (Locke, 2001a, pp. 469-470).

A holistic concept inspired by a conscious spiritualism, was and still is to many Native American, a way of life, a way of viewing the universe as a whole. It was integral to the way they lived on the land and partook of the earth's abundant resources and there seems to be a growing resurgence in this way of thinking and living. How does one measure such knowledge? Perhaps we can't. Perhaps we just need to listen and learn. The great physicist, Albert Einstein is reported to have said "Not everything that counts can be counted, and not everything that can be counted, counts" (Quotations, 2012). When dealing with the complexities of social research this is particularly true and I would argue how much more so when looking at the marginalized groups of society such as the Native Americans, many of whom, through their traditional ways and knowledge, can contribute so much to a holistic discourse on addressing the plight of our planet's social-ecological systems. In autumn 1977 The *Hau de no sau nee* of the Six Nation Confederacy addressed the Western World through a United Nation's Non Governmental Organization (NGO) forum in Geneva, Switzerland raising "a call for consciousness of the Sacred web of Life in the Universe" (Medina, 2006, pp. 247-248). Here is some of that address: ¹

Our ancient teaching warned us that if Man interfered with the Natural Laws, these things would come to be. When the last of the Natural Way of Life is gone, all hope for human survival will be gone with it.

¹ (see Appendix 1. for more excerpts from this U.N. address)

... experience has taught us that there are few who are willing to seek out a method for moving toward any real change. But, if there is to be a future for all beings on this planet, we must begin to seek the avenues of change

The people who are living on this planet need to break with the narrow concept of human liberation, and begin to see liberation as something that needs to be extended to the whole of the Natural World. What is needed is the liberation of all the things that support Life -- the air, the waters, the trees -- all the things that support the sacred web of Life.

The traditional Native peoples hold the key to the reversal of the processes in Western Civilization that hold the promise of unimaginable future suffering and destruction. Spiritualism is the highest form of political consciousness. And we, the native peoples of the Western Hemisphere, are among the world's surviving proprietors of that kind of consciousness. We are here to impart that message.

Many American Indians still speak of the *old ways*, particularly the elders and tribal leaders. This indigenous knowledge of the old ways continues to trickle down the generational lines. Indigenous knowledge and knowledge systems that integrate indigenous and science-based knowledge has been written about extensively. see for example: (Fikret Berkes et al., 2009; Fikret Berkes et al., 2000; Gadgil et al., 2003; Kerkhoff et al., 2006; Mauro et al., 2000; Peloquin et al., 2009; Pierotti, 2000; Wilson, 2004). Such a blending of experiential and experimental knowledge into a social-ecological framework fosters a more holistic design to eco-management and through its synergistic approach is supported by cultural values that do not segregate people and their dependence on local ecosystems. In doing so, the community begins to build resilience and adaptive capacity into the overall local social-ecological system.

RESILIENCY, ADAPTIVE CAPACITY, AND SUSTAINABILITY

Sustainability as a discipline along with its corollaries, sustainable development and sustainability science, take a long-term interdisciplinary approach to reconciling society's developmental goals with the earth's environmental constraints. A common but all-encompassing human-centric definition of sustainability comes from the Brundtland Commission where it defines sustainable development as humanity's ability "to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs" (NRC, 1999, p. 23). In a resilience framework, as will be further explored below, Holling (2001) defines sustainability simply as the capability to create, test and maintain adaptive capacity. Adaptive capacity is the capacity to adapt to and shape change (F. Berkes, et al., 1998).

The emergence of sustainable thinking since the 1980s has given rise to *sustainability science* that looks beyond the foundational disciplines to focus on understanding emergent complex dynamics stemming from social-ecological systems (Clark, 2007). This section will explore some of the concepts embedded within sustainability and sustainability science. Sustainability science and its corresponding discourse, through a variety of integrated disciplines involving the physical, natural and social sciences, addresses numerous interrelated topics including but not limited to: ecosystem services, humanity's well-being (health, disease, food security), land use change and trade-offs, climate change, governance, and knowledge and action. As pointed out by Berkes et al. (2003), sustainability science is being touted by some as the birth of a new kind of science, diverging from established classical western-science methodology due to shortcomings with classical hypothesis testing to handle

complexities; existence of long time lags between actions and consequences and having to deal with nonlinearities. Further complications stem from the scientific observer being unable to stand outside the coupled system being observed. As such, sustainability science (SS) is evolving new methodologies and learning concepts that generate semi-quantitative models based on qualitative data that often comes from case studies. SS is a science that explores techniques of adaptive management and experimental policy, which are field-based disciplines that emphasize action-in-doing. SS is also a science that seeks to work in parallel with traditional methods of scientific inquiry. SS seeks to reverse-engineer undesirable consequences in efforts to find pathways that can avoid negative future outcomes. Scientists, practitioners and the general public collaborate in efforts to produce trustworthy knowledge and judgment that is both grounded in social understanding but still scientifically sound (Fikret Berkes, et al., 2003).

I hold to the view that sustainability and its corresponding discourse, science, and policies that are emerging out of the sustainability construct, are giving rise to far reaching practical applications for humanity's survival. The longer humanity takes to apply change and adapt new behaviors of change at multiple scales that transition toward a more sustainable pattern of living as a balanced social-ecological planetary system, vulnerabilities will continue to exacerbate due to destructive cyclic exchanges between earth's geo-bio physical systems and anthropogenic social systems—all intricately integrated.

The journey towards global sustainability continues to give rise to a nest of differing opinions regarding critical path trajectories to achieve global sustainability. As noted by the National Research Council of the National Academies there is an urgent

need to “design strategies and institutions that can better integrate incomplete knowledge with experimental action into programs of adaptive management and social learning” (NRC, 1999, p. 10). However, since the launch of this concept in the 1980s the discourse has focused primarily on environmental and economic dimensions with limited attention given to social, political and cultural factors, including human behavior that remains a fundamental driver behind many of the contemporary issues. If human behavior is seen as a root cause for our present global environmental predicament, then it seems not only logical, but imperative to address human behavior as part of an integrated search for long-term sustainable solutions. The International Human Dimensions Programme on Global Environmental Change supports such a view:

Human actions currently dominate the Earth’s great biophysical cycles, and are, in aggregate, responsible for a variety of largescale environmental changes from climate change to loss of biodiversity or changes in the land cover. There is no way to address such problems effectively without altering human behavior individually and collectively. It is no exaggeration to say that the Earth is moving into an era properly called the Anthropocene. Through this knowledge, it has become clear that addressing largescale environmental issues, and fostering sustainable development will require a concerted effort on the part of researchers who focus on human behavior (IHDP, 2010).

The Intergovernmental Panel on Climate Change notes that if sustainable development trajectories are to be articulated, humanity must enforce a greater magnitude of integration between the natural and social disciplines (Sathaye et al., 2007). This has raised key questions in the literature such as how do we effectively incorporate the dynamic interactions between nature and society into emerging models and conceptualizations that integrate human development and the earth’s systems in a sustainable manner? (Kates, 2001).

The construct of an epistemology of sustainability perhaps warrants a cursory look back at history from which both experiential and theoretical knowledge and understanding of human interaction with the environment has evolved. Although a comprehensive evaluation such as this falls outside the scope of this research, a cursory look at the ecological milestones that Morris (2009) has uncovered does show there to be a track record of sustainability-oriented thinking dating back to 400 B.C. by the Greco-Roman and Chinese empires. Examples include Herodotus' discussions on mutualism, Plato's exposition on resource depletion, Rome's exhibition of ecosystem services as well as resource depletion, the Qin Dynasty's environmental protection laws and Taoist philosophy of humanity being a part of nature's whole rather than being a master over it. The next 2000 years are peppered with examples that exhibit sustainable practices and practices of environmental degradation foreshadowing a need for sustainable behavior change. The positive historical examples pointing towards sustainable practices are few leaving the preponderance of historical social-ecological feedbacks as negative—at least as depicted by Morris's (2009) historical survey of ecology.

By the 1980s there was a serious push by global institutions to take action in addressing the pressing global biophysical environmental concerns. Previous attempts to bring about an awareness of pressing social and ecological issues effected local and regional impact but perhaps were not taken seriously enough by a critical mass of people at high enough levels to gain traction to make a sustaining global impact in behavioral change. Examples might include Malthus' work on population growth and food security, warning in 1826 of imbalances between population growth and the earth's ability to produce sufficient sustenance—language that perhaps suggests a carrying capacity for a

global social-ecological system. Another example might be Rachel Carson's *Silent Spring* (1962) that is credited for spawning American Environmentalism and had global influences but cannot be said to have initiated the sustainability movement. It wasn't until the 1980s when global traction on a theme of sustainability thinking began to dig which was no doubt inspired by an evolution of such global awareness and thought. This came about with the launch of the World Commission on Environment and Development as spearheaded by the Brundtland Commission reports. It was here that the notion of *Sustainable Development* was born and further cemented into governmental and NGO thinking at the 1992 Rio Earth Summit. As such, I would conjecture that sustainability and its corollaries will come to be regarded by future historians as a 20th century emergent phenomena brought on initially by an over consuming western industrial society that quickly transitioned to a global competitive phenomenon.

Interwoven with the science of sustainability is the concept of resilience that in an ecological context was first introduced by Holling (1973) to evaluate non-linear dynamics in ecological systems but that has received considerable attention over the years by many disciplines. A more contemporary definition of resilience states that resilience "is the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, identity, and feedbacks" (Walker et al., 2004).

In a social-ecological context, the resilience framework involves adaptive complex system thinking involving nonlinearities, feedback loops, unpredictability, adaptability and vulnerability. As discussed in Berkes, et al. (2003, p. 13) the Resilience Alliance (2002) identifies three defining characteristics of a resilient system:

- The amount of change the system can undergo and still retain the same controls and function and structure, or still be in the same state, within the same domain of attraction;
- The degree to which the system is capable of self-organization;
- The ability to build and increase the capacity for learning and adaptation.

In the context of social-ecological systems, resilience may be thought of in terms of the ‘livelihood security’ of a group or society of people. It is about how societies adapt to externally imposed change. Resilience and adaptability are interrelated. As resilience grows so will be the ability to absorb shocks and perturbations, allocate needed resources and adapt to change. The opposite of this then must also be true: as resilience of a system wanes, the vulnerability of its agents, institutions, resources, and society as a whole system increases and this comes from a weakened ability to adapt to change, or the system’s overall adaptive capacity. Nelson, et al. (2007, p. 5) identifies the following three characteristics of a social-environmental system’s ability to adapt, that is, its adaptive capacity: “the degree to which the system is susceptible to change while still retaining structure and function, the degree to which it is capable of self-organization, and the capacity for learning.” Holling introduced the idea of nested dynamic hierarchies of adaptive renewal cycles interacting at multiple scales within a given ecological patch such as a forest system (Gunderson et al., 2001). First defined by Holling (1986) the adaptive cycle is metaphoric to describe four commonly occurring phases of change in complex systems: exploitation, conservation, creative destruction, and renewal (see Chapter 5). This ecological concept has also been applied to social-ecological systems thinking using heuristic modeling (F Berkes, et al., 2003) to capture some of the commonalities that exist in various kinds of cyclic change. A social example given by Berkes, et al. (2003) is the cyclic path of an empire starting out small and

vibrant, growing, institutions becoming rigid, and eventually collapsing that then gives rise to new nation states. In a social-ecological context, systems goes through an exploitation phase of pioneering and rapid development and then into an established or climactic phase where resources begin to be conserved and managed but that leads to rigidity and stiffness in the system and institutions. It is during this phase that a system is most vulnerable to external disturbance and perturbations. When surprise occurs there is a sudden release in the system and built up or *stored capital*. The system goes through a rapid phase of release and adjustment and it is in this stage where novelty and innovation are most likely to occur before going into a stage of reorganization. Holling refers to the latter two stages (release and reorganization) as the *back-loop* (F Berkes, et al., 2003).

Adaptation and vulnerability are essential concepts to understanding complex social-ecological systems within a resilience framework perspective. Adaptation or adaptability as defined by Walker et al. (2004) “is the capacity of actors in a system to influence resilience. In a social-ecological system, this amounts to the capacity of humans to manage resilience” (Resilience Alliance, 2002) and in the social-ecological context can involve building adaptive capacity, as noted by Nelson et al. (2007). Given the above, would it not also hold to suggest that building capacity, be it individual, community or institutional, can enhance adaptability? In this context, capacity building might refer to enhancing or strengthening the ability of individuals, a community or institutions to bring about change or influence resilience. The same authors also define vulnerability of a system as being its susceptibility to disturbance due to exposure to perturbations, sensitivity to perturbations and the capacity to adapt. In the context of a social-ecological system, disturbance may be understood to be a “discrete event in time coming from the

outside, that disrupts ecosystems, communities, or populations, changes substrates and resource availability, and creates opportunities for new individuals or colonies to become established” (Resilience Alliance, 2002; R. L. Smith, 1990). Adger (2006) offers a slight modification regarding social vulnerability as being a function of a system’s available resources for ready use which entails an efficient distribution system and institutions capable of mediating interactions. In this social context, I argue this to be necessary but not sufficient. It begs the question of how we define sustainable capacity in a social system—is it merely a capable complex network of material resources or does it involve a deeper level of complexity constituting a vibrant network of healthy human beings in mind, body and spirit? Can capacity within a social-ecological system that is to withstand severe change be acquired or maintained sustainably in a society that claims and exhibits normative adversarialism (Karlberg, 2004)? I explore such questions and thoughts in the next section through a synthesis of many of the foregoing concepts.

In the context of my research a primary goal of the collaborative process as it unfolds is to build capacity. This was certainly the case concerning myself and I believe others engaged in the process have also experienced a measure of capacity building. An example of collaboration and capacity building that has been explored in the field includes Arnold & Fernandez-Gimenez (2007) in their work with the Tohono O’odham Tribal Rangelands in Arizona where they show an increase in ‘social capital’ through their participatory curriculum development and research process with demonstrations of quality and validity through methods of post-positivist qualitative research. Reid et al. ((2009) through applications of a continual engagement model showed how progress achieved by the protracted project could build capacity at the individual and institutional

levels by engaging participants and integrative processes at multiple levels; noting that the researchers themselves built capacity as well during the process. Another collaborative-based case example comes from Fazey et al. (2010) in the Solomon Islands focused on helping local communities build capacity and to understand and find their own solutions to their own problems. Their findings concluded with assessments showing promotion of learning and understanding; a building of capacity for communities to manage challenges; a fostering of local ownership and responsibility for problems and a setting of precedents for future participation in decision-making.

Due to the complexities and nonlinearities in social-ecological systems I am attempting to explore new avenues by taking a semi-quantitative approach, using qualitative data in a soft systems environment applied through agent-based modeling. Hard system methods have clearly defined objective functions while soft systems do not have clearly defined objective functions at the outset and in fact may begin with competing notions of what the objectives should be. Collaborative learning takes this soft systems approach in order to meaningfully assess multiple world views in a non-prescriptive manner (Daniels, et al., 2001). Similar sentiments are argued by Smit and Wandel (2006) stating that researchers do not specify a priori determinants of adaptive capacity in the community as these are identified from the community itself through collaborative involvement of stakeholders. Furthermore, simulation modeling can be a means for capacity building. Van den Belt (2004, p. 3) states, “Models offer us the ability to expand our mental capacity in ways that enable us better to understand ecosystems and the implications of our many small management and policy decisions as they relate to ecosystem and human health.”

AGENT-BASED MODELING

Agent-based modeling (ABM) is a field of computational or simulation modeling. Simulation modeling was born out of the field of *system dynamics* and essentially “provides a structured process based on dynamic systems thinking to include the most important aspects of a problem in a coherent and simple but elegant simulation model” (van den Belt, 2004, p. 6). ABM is sometimes referred to as multi-agent modeling or individual-based modeling and dates back to the 1940s under the term cellular automata by von Neumann (Janssen et al., 2006). In the field of ecology, ABM dates back to the 1980s and was deployed on the argument that genetic uniqueness needed to be accounted for at the individual level and that individual interactions take place at the local scale (Houston, 1988). The ABM application to collective human behavior in the social sciences can perhaps be dated back to Thomas Schelling (1971) where he manually modeled the behavior of segregation using dimes and pennies. When looking at collective behavior through ABM three core themes have typically been prevalent in the first generation of ABM: spatial and temporal patterns, social contagion, and cooperation. More recent generations are beginning to address such areas as genuine predictiveness, experiential and experimental synthesis and internal representativeness of agents (Goldstone et al., 2005).

ABM is essentially a modeling or simulation of individual autonomous agents within a system or environment. ABM seeks to examine the effects of agents on a system as a whole and their interaction with that system. A key feature of ABM is that it deals with system complexity and enables the modeler to explore this complexity in non-linear ways resulting in outcomes that could not have been seen just through an analysis of the

individual agents themselves. Instead, it is the autonomous interaction of the agents operating within simple heuristic rules under certain assumptions and towards a given objective in their given environment that may give rise to unexpected outcomes – in other words, the whole is greater than the sum of the parts. Emphasis is on the *agents* and not on statistical variables and this approach is fully in line with sociological theory (E. Smith et al., 2007; Tubara et al., 2010).

Explicit models have value because assumptions are made known that give rise to certain outcomes and when the assumptions are altered, the outcomes are altered. It is through such sensitivity analyses where tradeoffs and uncertainties are revealed that models can play a key role in honing in options for decision making (Epstein, 2008). Grimm and Railsback (2005, p. 22) put it rather succinctly, “the purpose of modeling is to solve problems or answer questions ... a model may address a scientific problem, a management problem, or just a decision in everyday life... to solving real-world problems, simplified models are the only alternative to blind trial and error ...”. It is this *simplification* aspect that Epstein (2008, p. 4) addresses in terms of the need to “illuminate core dynamics” and that modeling although incomplete, over simplifying and even if altogether wrong, can offer “fertile idealization”, i.e. usefulness. Epstein then quotes George Box and Picasso respectively: “All models are wrong but some are useful” just as “Art is a lie that helps us see the truth”. Epstein (2008, p. 3) list numerous reasons for modeling beyond the most commonly stated reason—prediction of outcomes, such as simply to explain, to guide data collection or illuminate core dynamics, to discover new questions or promote a scientific habit of mind, train practitioners or inform a policy discourse, and to educate the general public.

These in fact extend beyond just reasons to model, they are outcomes and results of modeling as well, and in the context of my research, modeling is being used for many of the reason listed above as well as a means for capacity building, collaboration and raising the level of awareness of critical linkages between the environment and humans.

Van den Belt (2004) also states that simulation modeling, being born out of system dynamics, provides a way to study system change and behavior through an identification of basic building blocks that help to explain core behaviors and where feedback loops and time lags help to identify and characterize the intricate relationships between a system's foundational building blocks. The modeling of these systems helps us to systematically understand these complexities and uncertainties involving time lags, feedbacks and nonlinearities (van den Belt, 2004, p. 3). By altering time lags and scale parameters through the modeling process, policy makers can overcome disconnects of time and space. This is done by collapsing time and space into a time frame that will enable them to explore consequences of actions that would normally take place over long time periods that may not be in sync with institutional structures (Costanza et al., 2001; van den Belt, 2004).

A particular method of model building is mediated modeling which is “based on system dynamics thinking but emphasizes the interactive involvement of affected stakeholders in the learning process about the complex system they are in. It allows a group of stakeholders to understand how seemingly small decisions may spiral a system onto an undesirable course. Such understanding provides opportunities to jointly design strategies to abate the negative spiral or to curb a trend into a more positive one” (van den Belt, 2004, p. 3). It is in essence a method of collaborative engagement and is a key

method in my research. I discuss the fieldwork using this method in Chapter 3. Inherent in its design, mediated modeling aims for a collaborative team learning experience that elevates the shared level of understanding in a group and fosters a broad and deep level of consensus (van den Belt, 2004, p. 11). Further to the list of “why model?”, van den Belt explains how mediated modeling helps to structure a group’s thinking and discussion, stimulates joint learning among a group of individuals with varying backgrounds, all of which lead to a new way of learning and building knowledge as addressed in the above section on truth, knowledge and reality.

In essence, there are two classes of explicit models, *pure* models and *empirical* models. The *pure* models are abstract and theoretically built to mimic a phenomenon to generate, express and/or test theories and which may not always represent choices realistically (Moretti, 2002; Tubara, et al., 2010). *Empirical* models can be informed with both quantitative and qualitative data making them open to estimation and validation (Hassan et al., 2007; Tubara, et al., 2010). In such models, qualitative data are used to inform simulation rules and parameters (Chattoe, 2002; Tubara, et al., 2010) while quantitative data are used to assess the probability that a certain event takes place within a given population of agents (Gilbert, 2007; Tubara, et al., 2010). Tubaro and Casilli evaluate a general analytical framework for empirically informed agent-based simulations. They state that such a methodology provides a “sound and proper insight as to the behavior of social agents – and insight which statistical data often fall short of providing ... simulations can provide qualitative researchers in sociology, anthropology and other fields with valuable tools for: (a) testing the consistency and pushing the boundaries, of specific theoretical frameworks; (b) replicating and generalizing the

results; (c) providing a platform for cross-disciplinary validation of results” (Tubara, et al., 2010, pp. 59-60). Both qualitative and quantitative empirical information can be used as input data to study a given situation or it can be used to test a model with the aim of finding arguments within the model that can be generalized and tested against new empirical cases. However, this latter point is one of the key challenges in social science. The challenge is on how to develop models that not only remain applicable in specific cases but which can also be generalizable (Janssen, et al., 2006), or at least it is a challenge when trying to apply the rules of the classical scientific methods and perhaps we need to begin looking outside this box. Jansen and Ostrom (2006) suggest four categories where ABMs have been empirically tested: case studies, role playing games, stylized facts and laboratory experiments where the former two emphasize fitting the data to a special case and the latter two focus more on generalizability. As presented in chapter 3, I used a variation of two of these methods in addition to a combination of other methods that has given rise to a collaborative initiative to bring about change and awareness at the local level.

DISCUSSION: A CONCEPTUAL SYNTHESIS

In this discussion I propose that in the context of reflexive physical and social realities where each impacts and affects the other, vulnerability, resiliency and adaptive capacity are very much interrelated with truth, and the established ways humanity seeks knowledge and learns; all of which have an impact on the sustainability of social-ecological systems. Furthermore, a central and pivotal aspect of these complex

conceptual relationships is the degree of collaborative interaction or unity, based on a foundation of truthfulness.

In a social context, the collaborative process seeks to transform, transition, enable and empower for the betterment of the individual and the community but it is not a process that can always be used (Daniels, et al., 2001). There must be an initial drive and motivation to assemble and try the process. Within this context, the quality of outcomes is a function of the quality of inputs. Where rancor, hate, bitterness and selfishness consume the process and make it intractable, then it will fail unless some other form of mediation takes place that can sufficiently mitigate such concerns enabling the process to move forward. Where cooperation, patience, kindness, understanding and respect for example, are encouraged, developed and expressed then the dynamics of cooperation and mutualism begin to work and new thought and creative sustainable solutions will begin to emerge. Conceptually, the *Participatory Social Framework of Action / Collaborative Adaptive Capacity Building* (PSFA-CACB) model (Fig. 2.3) attempts to depict some of these interacting forces of human nature. When applied consistently and with a consistent application of the model core, that of *Collaborative Adaptive Capacity Building* (CACB), I believe such interacting forces will lead to a positive objective of sustainable decision making and a strengthening in individual and group capacity.

As the collaborative process steps forward in time there is a need for continuous open and free consultation where feedback on issues, concerns or actions go back to be reworked and reworked until the process can begin to move forward again in a positive direction. Key components to the PSFA-CACB model are the feedback loops. Within the context of a resilience framework, a social-ecological system can exhibit both positive

and negative feedback. A positive feedback loop occurs “when the output of a process influences the input of the same process in a way that amplifies the process, often in a

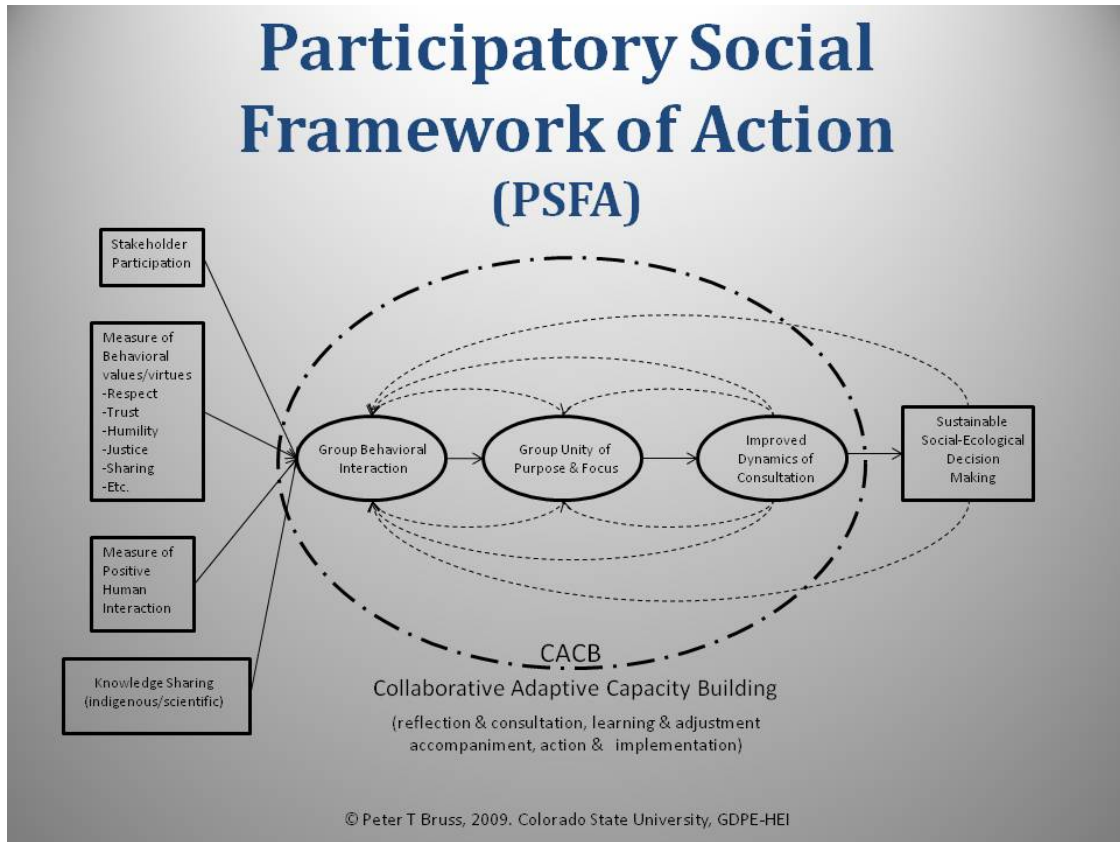


Fig. 2.3 PSFA-CACB Model

destabilizing manner” while a negative feedback loop occurs “when the output of a process that influences the input of the same process has a dampening or stabilizing effect, pushing the system towards an equilibrium” (Resilience Alliance, 2002; Bennett et al., 2005). This can be applied to the PSFA-CACB model where negative output along the continuum is cycled back to former stages and will continue this cycling until sufficient progress is made to move forward. In other words, the system remains in an equilibrium loop. However, sufficient positive outcome at any given stage will amplify

the process forward towards the objective. In the context of this model, therefore, the goal is to move forward and not remain in a state of equilibrium.

The theoretical concept is that as progress is made through these iterative stages, individual and ultimately community capacity is strengthened and knowledge is discovered, shared and in some cases may be generated which empowers the group decision-making process to make more sustainable decisions. The cumulative effect of this leads to greater adaptive capacity within the community and ultimately greater resilience by the whole system to withstand endogenous or exogenous shocks and disturbances. When carried out in a constructive atmosphere conducive to growth, these nested and interconnected cycles can be a contagious source of upliftment, engagement, empowerment and capacity building. This is a framework of limitless possibilities based on human dynamics, creativity and interaction. It is dependent, however, on a positive flow of energy that is generated and co-generated through cyclic interactions between people. Such an energy exchange is known to be contagious (Holman et al., 2007, p. 7).

As the ultimate outcome of the PSFA-CACB model is to attain sustainable decision-making, the question may be asked: How can this be gauged? Sustainability is not really a measurable goal in the short-term but there are ways to know if progress is being made and the process is transitioning in the right direction. Holman, et al. (2007, p. 60) in *The Change Handbook* provides four broad areas to monitor: Direction, Energy, Distributed Leadership and Appropriate Mobilization of Resources that are touched upon below.

The core of the PSFA-CACB model is wrapped in an iterative collaborative adaptive capacity building process that can be thought of as the engine to the model. As

individual capacity grows in a positive constructive direction, confidence and trust in the process and between participants is strengthened that enables further positive change. This core process is broken down further in Fig. 2.4, which depicts a cyclic interaction of collaborative reflection and consultation, learning and adjusting, accompaniment, action, and implementation. These can all occur at multiple scales, spread out over time, space and levels as participants interact. This may at times be the whole system interacting together or smaller groups of a few or even one-on-one interactions. What is key is that

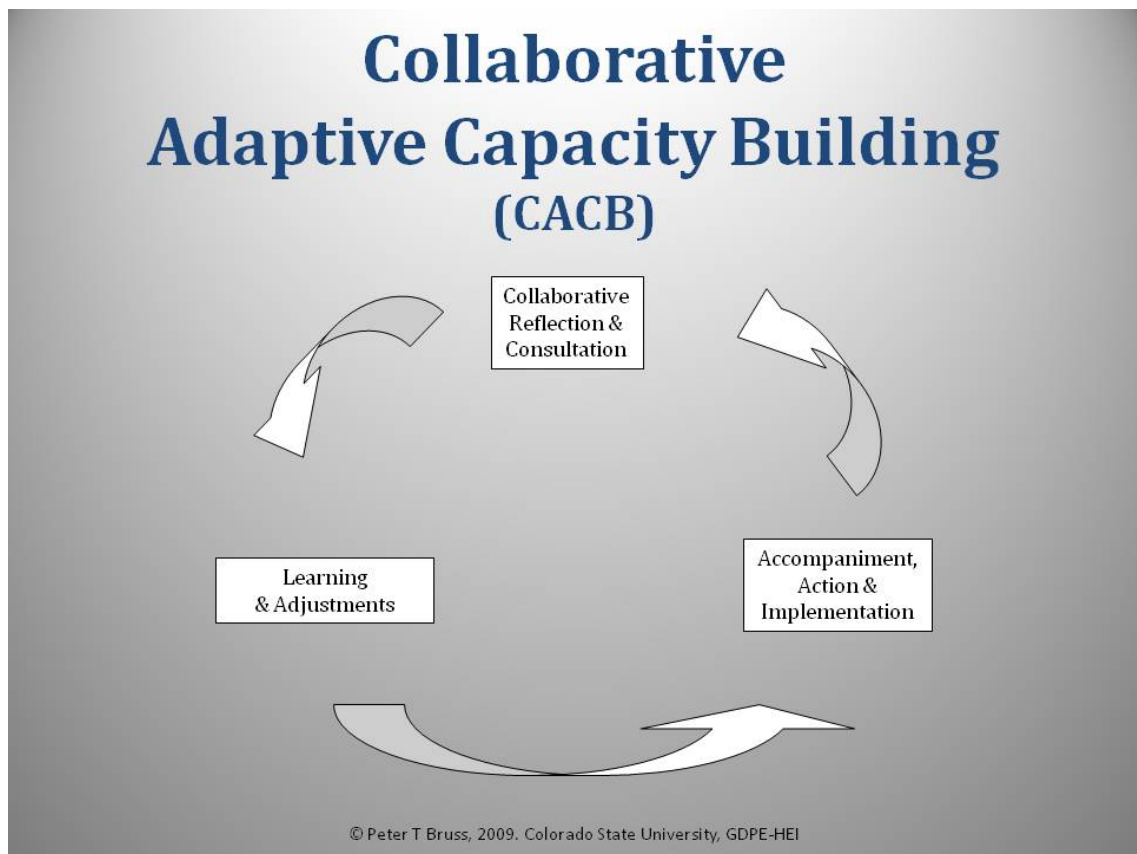


Fig. 2.4 Collaborative Adaptive Capacity Building (CACB)

the process is iterative so that within a humble posture of learning and accompanying one another, adjustments are made as deemed necessary to move forward with action and implementation and then through a consultative/reflective engagement new learnings and

adjustments come about and so forth. Aspects of this iterative technique are being applied in a multitude of practical ways throughout the international Baha'i community as well as other international programs such as FUNDAEC as discussed above. However, illustrating the specific interlinking dynamics of the PSFA-CACB model and applying this model in the context of social-ecological systems thinking is, I believe, a novel pursuit.

A corollary can be linked to this capacity-building notion through the concept of power and knowledge and how they are used. Earlier in this chapter I briefly discussed how Karlberg (2004, pp. 23-35) unpacks the predominate models of power: *power to* and *power over* and repacks them into just one model of *power as*. To exercise *power over* something or someone is in effect exercising *power to* dominate and this stems from the established culture of normative adversarialism. He then constructs a new model: *power as capacity* under which there are two relational domains; one of adversarialism that exhibits *power against* expressing competitive behavior, and one for mutualism that exhibits *power with* expressing cooperative behavior. I believe the model I am proposing here fits within Karlberg's *power as capacity* dynamic as the PSFA-CACB focus is to build adaptive capacity through collaboration.

I believe that in the context of any collaborative engagement, irrespective of scale (temporal or spatial), there needs to be a continual awareness and reminding of our actions and behaviors. Unless or until we acknowledge the impact that *power* can have over people and in processes in terms of building or destroying capacity we have not fully understood the true meaning of a collaborative engagement process. There is however, another aspect that needs to be addressed which is closely linked to power and

that is *knowledge*. Power and knowledge are linked at the hip so to speak and history has played out scenes over and over where certain groups seek to dominate other groups not so much through might (although this also happens far too often) but through education and knowledge.

I make the theoretical argument that a complex social-ecological system exhibits degrees of *adaptiveness* to change in an order of magnitude to its capacity to adapt as a collective whole as well as by the adaptive capacity of its individual agents that comprise the system. In other words, an adaptive social-ecological system's ability to withstand disturbances, perturbations and change and be less vulnerable, i.e., its overall measure of resiliency, is at least in part, a measure of its capacity to cope and adapt. Coping and adapting have similarities but differ most significantly through their expressions of change at different time scales—coping can be considered to be a short-term process whereas adapting occurs over a longer time frame (Nelson, et al., 2007). In this same line of thought, evolving or evolution spans a much greater temporal scale—perhaps thousands and even millions of years.

I also argue that capacity can be built either due to a reaction to disturbance or through proactive measures, each under different circumstances. *Reactive capacity building*, if I could coin this concept, is initiated involuntarily and comes through conscious and unconscious change out of responses to disturbances. I would argue that it is intuitive to think that these types of changes are often deep and sustainable when made with thought and good decision making due to the heat and fire (proverbial but sometimes literal) of the disturbance from which the change is motivated. However, *proactive capacity building* (to coin the concept of the counter to *reactive capacity*

building) is done consciously and typically in periods of calm and rational thinking but without the fusing heat of disturbance. If *proactive capacity building* is to be sustainable it should be well conceptualized and integrated at multiple scales within the context of its application. This is where effective collaborative engagement processes can play a significant role. One way to do this might involve engaging a community and its agents to build strength through the collaborative acquisition and utilization of power and knowledge that can be utilized for the acquisition of appropriate technologies, assets and entitlements. See for example Ericksen (2008) about assets and entitlements. My argument here is that there should be a primacy given to empowerment and knowledge building for sustainable capacity building to occur, i.e., that *sustainable capacity building* is more than accumulation of human capital, it must involve a building of social and cultural capital as well. Human capital is considered to be an extension of physical capital but which is less tangible consisting of skills and education (Coleman, 1988). Like physical capital, human capital emerges from the utilization of renewable and non-renewable resources (natural capital) through applications of economic activity (Nelson, et al., 2007). Cultural capital is rather more loosely defined to include all social expressions of cultural value that enable societies to engage and modify the natural environment. These might include world views, value systems, philosophies, religion, spirituality, ethics and traditional knowledge systems (Nelson, et al., 2007). Another form of capital that relates to cultural capital is social capital that perhaps can be viewed as a subset of cultural capital. Social capital also plays a constructive role in influencing human capital as economic activity is a product of social capital. Coleman (1988) writes of social capital as emerging from the relations and networks among people. Regardless

of the types of capital, what is key is that from a systems perspective, physical, human, cultural and social capital are interrelated as they are manifestations of human adaptation to the natural world and dictate how humanity defines and uses natural capital (Nelson, et al., 2007). It is in essence the reflexivity between social and physical reality as I have defined above. From another perspective, also discussed above, Karlberg (2004) discusses how the fabric of our western-influenced global social reality is steeped in *normative adversarialism* stemming from a tripartite system of contests between competing social domains of politics and law that are hierarchically positioned under and subservient to the primacy social domain of economics (see endnote 2). This tripartite hierarchy is derived out of the nature of adversarialism and contests that arise not from human nature but from human culture and has resulted in a failure of both state and moral regulation of market activities. The legacy it is leaving behind is one of steadily increasing disparities of wealth and poverty and anthropogenic degradation of ecological systems.

Capacity building needs to be approached comprehensively as noted by the National Research Council (NRC, 1999) calling for a nurturing of global and local institutions to focus on integrating place-based projects of cultural tradition with global knowledge systems. This implies an integration of method, scale and knowledge systems. As such, there are nested hierarchies of the capacity building process spread over time and space that needs to be enacted at multiple levels simultaneously. In this context, sustainable capacity building could be seen as a collaborative organic process that unfolds and emerges with successive feedback. At the individual scale, capacity building may start out as a simple educational or empowerment activity that then leads to

more complex tasks and networks that in turn go on to build capacity within institutions and communities over time. At the same time, there may be top-down initiatives that span institutions at different scales through governmental or non-governmental pathways. Progress and linkages may occur along linear or nonlinear paths. An example of such a linear and nonlinear path, bifurcating simultaneously at the local level, might be the empowerment and education of a junior youth in a community who goes on to accompany another junior youth in a local service project to clean up the environment (linear causality) but that in turn spawns a positive reaction by a parent or a peer in a different location who hears of the news and who decides to take some other form of positive action and this in turn causes another reaction (nonlinear causality).

Nonlinear phenomena are typical in complex systems. In the context of human behavior, such replicating actions can be contagious and they can be met with resistance by other non-conforming behavior. To address the former point, take for example group energy. Group energy is known experientially to be contagious and can result in peer to peer benefits and actions being replicated (Holman, et al., 2007). To experience positive contagion is to have an opportunity for further growth. To be met with resistance is to test the existing level of capacity within the system. Both scenarios can be a means for building capacity. Perhaps an area of focus for a future study would be to evaluate the extent a social system's ability to build sustainable capacity and thereby enhance its ability to adapt to environmental change, is related to its level of maturity in terms of the quality of its cultural and social capital as expressed through a measure of human virtue such as cooperation, mutualism, trustworthiness, humility, kindness and patience. Although Hardin (1968) made the argument that the commons, if left ungoverned, would

be destroyed, counter arguments have since been rationalized and modeled through game theory that this may not to be the case due to emergent positive human interaction such as cooperation and mutualism. See for example (Axelrod et al., 1981; Ostrom et al., 2007).

A further point to be made in closing is that capacity that has been acquired or built up can remain latent within the system until it is tested or it may be utilized and put into action within the system through action and service. To remain latent runs the risk of *capacity loss* much like an idle battery and if not recharged may not be ready to respond sufficiently to meet demands placed upon the system when needed. However, to apply *acquired capacity* systematically and at regular intervals in modes of service and action would be preferable. In doing so, the system and its agents are engaged and such action and service act as feedback informing and positively reinforcing the system and enhancing its capabilities.

In Chapter 3 the concepts of collaboration and adaptive capacity building are explored at the field research level using participatory techniques of photovoice and artvoice as well as agent-based modeling and examined in a resilience framework.

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endnote

¹ Through correspondence-truth a true idea is an idea that positively corresponds to facts as arranged in the observable world – it is the correspondence between an idea and a fact. Empiricism as brought forth during the Age of Enlightenment (Reason) gave rise in part to our contemporary classical model of science and positivism throughout the period of modernity and may be differentiated from two other means of verifying truth, rationalism and pragmatism. Rationalism is based on the truth-method of coherence where an idea is one that coheres logically with a set of beliefs already established by a group of people or a society. Coherence-truth establishes a positive relationship between two things that are the same, two ideas. Pragmatism results in pragmatic-truth that is derived from the usefulness of an idea that violates neither coherence-truth nor correspondence-truth.

² As stated by Karlberg (2004, p. 51) “Political and legal contests are expensive and economic contests determine who has the money to prevail in them. Hence political and legal contests are inextricably linked to economic contests. Furthermore, one of the functions of political and legal institutions is to regulate market activity. At a minimum, political and legal institutions must legislate and enforce a basic framework of property law and contract law, as well as laws governing gross criminal activities in the marketplace. Political and legal institutions also potentially legislate and enforce laws designed to reduce extreme disparities of poverty and wealth, as well as laws designed to foster the sustainable stewardship of the natural resources upon which the economy ultimately depends. Economic contests are thereby further linked to political and legal contests”.

³ This paper is difficult to locate but parts of it are in (Lample, 2009, p. 137). Similar sentiments are expressed in papers published online at www.globalprosperity.org.

⁴The Navajo reservation was established in 1868 and the Hopi reservation was later established in 1872 based on a joint use area (JUA) provision. This was followed by a US Government executive order in 1882 giving Hopi title to their sacred lands that they had traditionally used. This European-western style of meddling with land rights and boundaries (Medina, 2006) has led to a century-plus of wrangling and divisiveness in the region. In 1974, a Congressional Act known as the "The Navajo-Hopi Land Settlement Act" or simply the "Relocation Act" (Public Law 93-531) that enacted partitioning of the JUA and established the Navajo-Hopi Indian Relocation Commission (NHIRC) resulted in the displacement of 10,000 Navajo and 109 Hopi (Locke, 2001a). Ground zero for much of the dispute has been over mining and property rights issues in the Black Mesa area. It is a commonly held view by the local community that this enactment was nothing more than a land-grab attempt by corporate energy interests (Locke, 2001a). By conservative estimates the land holds a wealth of minerals and energy deposits in the form of oil, natural gas, uranium and coal (Ahni, 1985).

APPENDICES

Appendix 2.1 The Haudenosaunee of the Six Nation Confederacy

Sacred Web of Life in the Universe (1977 - Excerpts)

Today the species of Man is facing a question of the very survival of the species. The way of life known as Western Civilization is on a death path on which their own culture has no viable answers. When faced with the reality of their own destructiveness, they can only go forward into areas of more efficient destruction. The appearance of Plutonium on this planet is the clearest of signals that our species is in trouble. It is a signal that most Westerners have chosen to ignore.

The air is foul, the waters poisoned, the trees dying, the animals are disappearing. We think even the systems of weather are changing. Our ancient teaching warned us that if Man interfered with the Natural Laws, these things would come to be. When the last of the Natural Way of Life is gone, all hope for human survival will be gone with it. And our Way of Life is fast disappearing, a victim of the destructive processes.

... our essential message to the world is a basic call to consciousness. The destruction of the Native cultures and people is the same process that has destroyed and is destroying life on this planet. The technologies and social systems that have destroyed the animal and plant life are also destroying the Native people. And that process is Western Civilization.

... experience has taught us that there are few who are willing to seek out a method for moving toward any real change. But, if there is to be a future for all beings on this planet, we must begin to seek the avenues of change.

The processes of colonialism and imperialism that have affected the Hau de no sau nee are but a microcosm of the processes affecting the world. The system of reservations employed against our people is a microcosm of the system of exploitation used against the whole world. Since the time of Marco Polo, the West has been refining a process that mystified the peoples of the Earth.

The majority of the world does not find its roots in Western culture or traditions. The majority of the world finds its roots in the Natural World, and it is the Natural World, and the traditions of the Natural World, that must prevail if we are to develop truly free and egalitarian societies.

It is necessary, at this time, that we begin a process of critical analysis of the West's historical processes, to seek out the actual nature of the roots of the exploitative and oppressive conditions that are forced upon humanity. At the same time, as we gain understanding of those processes, we must reinterpret that history to the people of the world. It is the people of the West, ultimately, who are the most oppressed and exploited. They are burdened by the weight of centuries of racism, sexism, and ignorance that has rendered their people insensitive to the true nature of their lives.

We must all consciously and continuously challenge every model, every program, and every process that the West tries to force upon us. Paulo Friere wrote, in his book, the "Pedagogy of the Oppressed," that it is the nature of the oppressed to imitate the oppressor and by such actions tries to gain relief from the oppressive condition. We must learn to resist that response to oppression.

The people who are living on this planet need to break with the narrow concept of human liberation, and begin to see liberation as something that needs to be extended to the whole of the Natural World. What is needed is the liberation of all the things that support Life -- the air, the waters, the trees -- all the things that support the sacred web of Life.

We feel that the Native peoples of the Western Hemisphere can continue to contribute to the survival potential of the human species. The majority of our peoples still live in accordance with the traditions that find their roots in the Mother Earth. But the Native peoples have need of a forum in which our voice can be heard. And we need alliances with the other peoples of the world to assist in our struggle to regain and maintain our ancestral lands and to protect the Way of Life we follow.

We know that this is a very difficult task. Many nation states may feel threatened by the position that the protection and liberation of Natural World peoples and cultures represents a progressive direction that must be integrated into the political strategies of people who seek to uphold the dignity of Man. But that position is growing in strength, and it represents a necessary strategy in the evolution of progressive thought.

The traditional Native peoples hold the key to the reversal of the processes in Western Civilization that hold the promise of unimaginable future suffering and destruction. Spiritualism is the highest form of political consciousness. And we, the native peoples of the Western Hemisphere, are among the world's surviving proprietors of that kind of consciousness. We are here to impart that message.

CHAPTER 3

CHAPTER 3

RESEARCH METHODS AND RESULTS: PHOTOVOICE, ARTVOICE, AND THE PSFA-CACB MODEL

INTRODUCTION

This chapter covers the results of the collaborative field exploration that took place through regular and sometimes intermittent field site visits to Burntwater, AZ in the Houck Chapter of the Navajo Nation over the course of nearly 24 months and some 30,000 road miles. My fieldwork was conducted through a Navajo Nation Human Research Review Board approved study entitled *A Community Participatory Exploration of the Environment, Renewable Energy, Human Capacity Building and Entrepreneurial Solutions as Seen by the Navajo through Photo, Art and Stories* (NNR-10.282). The results from this field study are an integral part of this dissertation and my theoretical inquiries.

My overall research results stem from the application and development of two mutually supporting models, one conceptual and the other agent-based. In this introductory section, the research questions are presented followed by a description of the study area and then a review of the various methods used. Subsequently, the next sections follow a pre-designed tri-phase approach that I deployed to carry out the exploration. Each phase is described in detail followed by an analysis respective to each research question. Phase-I explored the initial steps taken to introduce the project into the area and to establish a baseline-understanding around some key concepts using qualitative elicitation methods, namely one-on-one interviews, focus groups and group

consultations. This was followed with implementing a core component of the collaborative participatory exploration—photovoice and artvoice—that was concluded with a community-wide gathering to share in the results. Phase-II formally introduced into the project the use of the *Participatory Social Framework of Action* (PSFA) conceptual model and its inner-core *Collaborative Adaptive Capacity Building* (CACB) during community gatherings. Phase-III involved the development of a two-tier agent-based model: *Taking Care of the Land – Human Environment Interactions* (TCL-HEI) that looks at behavior, action, economics and renewable energy in the form of a *Regional Cooperative Clean-Energy Economy* (RCCEE) framework. The TCL-HEI model is part empirical part theoretical. The concluding section to this chapter is a synthesis of the dual-model approach (PSFA-CACB, TCL-HEI) taken in relation to the research questions and a discussion on the results, learnings and implications.

The Research Questions

It is typical for research foci to change during work no matter the type of work being done. Miles, et al. (1994) make this point regarding social science using qualitative methods stating that it is often during the process of exploration that new thoughts, ideas and insights emerge. This was certainly the case in my research where the initial questions I had set up for inquiry at the beginning morphed and evolved through the course of this field exploration and discovery process into a final focus at this dissertation stage. At the outset, I had proposed the following framework of questions:

1. How do the Navajo of Houck, Arizona perceive:
 - Their local environment?
 - Their local energy needs?

- Entrepreneurial solutions to issues around the environment and energy?
 - Capacity building?
2. Can positive emergent human behavior arise from a dynamic process of human capacity building among the Navajo of Houck, Arizona during a community participatory exploration of and collaborative consultation on local sustainable entrepreneurial solutions to community environmental and renewable energy issues?
 3. What behavioral traits during consultative decision-making can be learned from the local Navajo of Houck, Arizona as they explore sustainable entrepreneurial solutions to their local environment and energy issues?

Through the process of exploration, these questions then evolved into what has now become the final focus of my research as presented in this dissertation. These questions are reiterated below to serve as a directional focus through this section. As set out in these questions, the over arching aim of this research is to explore and discover more holistic and collaborative ways to bring about awareness of environmental concerns that result in collective action to remedy or mitigate negative impacts on the environment. To this end, the following three questions seek results specific to the use of the dual-model approach introduced above.

Q1 – How can a participatory research process using photovoice, artvoice and applications of the *Participatory Social Framework of Action - Collaborative Adaptive Capacity Building* (PSFA-CACB) conceptual model create individual awareness to bring about collective change and sustainable action to improve the environment and address local energy needs?

Q2 – What can an agent based simulation model on cooperative behavior, *Taking Care of the Land – Human Environment Interactions* (TCL-HEI), tell us about the dynamic relationships between individual and collective awareness to bring about sustainable cooperative action and change regarding illegal trash dumping – an issue that was adopted by participants

in the local community and explored through photovoice, artvoice and the PSFA-CACB conceptual model?

Q3 – What might a theoretical *Regional Cooperative Clean-Energy Economy* (RCCEE) look like through the lens of the TCL-HEI agent-based model depicting a clean-tech waste-to-fuels process as a sustainable entrepreneurial solution to create energy and jobs, and what are some likely positive and negative consequences for the regional environment and economy?

Following an analysis of the individual models and their results, I present a synthesis on the discovery and learning from the application and development of these two models used in sequence as one overarching method to foster *collaborative adaptive capacity building*.

Q4 - How has *collaborative adaptive capacity building* as a participatory process using photovoice and artvoice brought about positive change through sustainable social action and how is this in turn building resilience to withstand disturbance and overcome vulnerability through collective cooperation and unity in action?

Q5 – How has this tri-phase dual-model (PSFA-CACB conceptual model; TCL-HEI agent-based model) collaborative research added value to problem solving in complex adaptive social-ecological systems?

Study Area – The Navajo Nation

The Navajo Nation is located on the high Colorado Plateau in the Four-Corner's region in the western third of the continental United States where the borders of Arizona, Colorado, New Mexico and Utah meet (Fig. 3.1). The region is a high plains desert ranging in altitude from 3,500 to above 10,000 feet covering four topographical regions: flat alluvial valleys, rolling upland plains, rugged table lands (mesas) and mountains (Kluckhohn, et al., 1974).



Fig. 3.1 The Navajo Nation

(Source: <http://www.navajobusiness.com/fastFacts/images/usmap.jpg>)

The Colorado Plateau is situated in the interior dry end of two seasonal moisture trajectories: summer convection storms from the Gulf of Mexico and winter storms from the Gulf of Alaska that create a climate boundary that is prone to shifting over long periods of time influencing vegetation growth and biodiversity (Schwinning et al., 2008). These changes in biodiversity are not only impacted by climatic drivers but also by human activity introducing invasive species, practicing range land grazing and the use of vehicles; all of which have been shown to severely impact the biological soil crust (BSC) comprised of cyanobacteria, microfungi, lichens, and mosses. The BSCs on the Colorado Plateau represent nearly 70% of the living landscape cover driving ecosystem functions and carbon (C) and nitrogen (N) cycles (Belnap, 1995; Schwinning, et al., 2008). Perhaps more importantly, due to persistent drought conditions, BSC plays a critical role in soil fertility and ecosystem health through soil particle cohesion and influencing the sizing of soil aggregates that in turn influence soil aeration, porosity, erosion, and moisture

retention and infiltration (Belnap et al., 1993; George et al., 2003; Schwinning, et al., 2008; Warren, 2003).

The Navajo, descendants of the Athapaskan group, who settled into this area formally refer to themselves as Diné (The People) who settled in Dinehtah (the land of The People) (Lapahie, 2005). An accurate translation of Diné has not been agreed upon due to the complexity of the Navajo Language. “Men”, “people” and “earth people” can also be acceptable translations but “The People” is most common (Locke, 2001a). Traditional belief is that the name Ni’hookaa Diyan Diné (Holy Earth People, or Lords of the Earth) was bestowed upon the Navajo (Lapahie, 2005). However, their Spanish given name “Navajo” is what non-Navajo use most often. Lapahie (2005) on his website describes the origins of the Navajo name as follows:

The Tewa Indians were the first to call them "Navahú", which means "the large area of cultivated land" because of their dominance over the Tewa domain. The Mexicans knew them as "Apaches Du Nabahú" (Apaches of the Cultivated Fields), where the word "Apache", meaning "Enemy", was picked up from the Zuni Indian language. The "Apaches Du Nabahú" were known as a special group somewhat distinct from the rest of the Apaches because of their beautiful and unique rugs and jewelry. Fray (Spaniard Priest or Monk of the 17th Century) Alonso de Benavides changed the name to "Navaho" in a book written in 1630. The American word for the Diné officially used was "Navaho" from the early 1900s until the early 1960s and then slowly changed to "Navajo". The Navajo Nation sometime between 1968 to 1970 officially used "Diné" instead of "Navajo" in referring to themselves.

The date of settlement of the Diné in this region is also disputed but through a combination of research methods such as analysis of Navajo oral tradition, excavated pottery and dendrochronology of tree rings from wood used to build hogans, the traditional Navajo dwelling, it can be said with some certainty that ancestral Navajo inhabited this region around 1,000 AD (Douglas, 1935, 1941; Locke, 2001a).

Today, the Navajo Nation spans an area across the Four Corners of just less than 14 million acres—about the size of West Virginia. It sits between four sacred mountains that designate four sacred colored stones in the Navajo Creation Story representing significant aspects of traditional Navajo religious beliefs that helps them live in harmony with both nature and their Creator (Lapahie, 2005):

Mount Blanca (Tsisnaasjini' - Dawn or White Shell Mountain)
Sacred Mountain of the East in the San Luis Valley, Colorado

Mount Taylor (Tsoodzil - Blue Bead or Turquoise Mountain)
Sacred Mountain of the South north of Laguna, New Mexico

San Francisco Peaks (Doko'oosliid - Abalone Shell Mountain)
Sacred Mountain of the West near Flagstaff, Arizona

Mount Hesperus (Dibé Nitsaa, Big Mountain Sheep, - Obsidian Mountain)
Sacred Mountain of the North La Plata Mountains, Colorado

These ancient geographic boundaries of the Navajo along with other valued features of the natural world are incorporated into the Navajo Nation Great Seal (Fig. 3.2).

The Great Seal bears a ring of protection represented by outward pointing arrowheads for each State of the United States that circles the Navajo Nation. The inner ring of red, yellow and turquoise, represents a rainbow of life giving waters and the Navajo hogan. It opens to the top signifying the openness of the Navajo Nation's sovereignty and is in the direction of east (hááaah) in the Seal. The round hogan is symbolic of the sun and its doors face east to greet the sun that is also depicted in the Seal, rising above four sacred mountains. All things are seen to come from the east; a direction signifying all things good and beautiful. Two green corn plants embrace four mountains and livestock. Corn and livestock sustain life for the Navajo and the yellow



Fig. 3.2 The Great Seal of the Navajo Nation
(Source: http://www.lapahie.com/Chapter_Email.cfm)

pollen of the corn is used extensively in ceremonies. The four mountains referenced above (black, turquoise, white, and yellow) depict the boundaries of the sacred land of the Diné in the Navajo Creation Story where the world began as a black island above that were four clouds (black, blue, white and yellow). These clouds were symbolic of successive worlds depicting themes of birth, propagation, flood, escape and continuing life (Lapahie, 2005; Locke, 2001a). Some of the symbolic features of the Seal are also incorporated into the Navajo Nation Flag (Fig. 3.3). Differing features incorporated into the flag include a map of the Navajo Nation with the darker brown color of the map depicting the original area of the 1868 reservation. The orientation of the flag is different from the Seal with north being set to the top as in standard cryptography; putting east to the right which is the proximity of Mt. Blanca (the White Mountain) in relation to the Navajo Nation – all under the arching Navajo Nation sovereignty, depicted by the rainbow. The inner seal on the map depicts the Navajo economy and social reality through agriculture, livestock, the hogan, the modern home, an oil rig, mining, forestry,



Fig. 3.3 The Navajo Nation Flag
(Source: http://www.lapahie.com/Chapter_Email.cfm)

a saw mill and fishing and hunting (Lapahie, 2005).

Ethnographic observations back in the 1940s by Kluckhohn and Leighton (1974) found that the Navajo had adapted themselves to the land and nature—unlike the white American who was seen to dominate and master the environment where “nature is often viewed as a malignant force that must be harnessed or shorn”(Kluckhohn, et al., 1974, p. 308). The Navajo were perceived as more passive, showing signs to affect moderate control and repairs on their environment but ultimately yielding to forces of nature that determined the success or failure of crops. Kluckhohn and Leighton (1974) draw out a clear difference in value orientation between the Navajo they studied and many white people stating “Their [white people] premise is that nature will destroy them unless they prevent it; the Navahos’ is that nature will take care of them if they behave as they should and do as she directs” (Kluckhohn, et al., 1974, p. 308).

The Navajo Nation is governed by elected representation and consists of local Chapters within governing agencies. Five governmental agencies surround the Hopi Reservation. My research took place in the Houck Chapter of the Ft. Defiance Agency

about 35 miles southwest of Gallup, NM just across the New Mexico State line into Arizona off I-40 (Fig. 3.4).

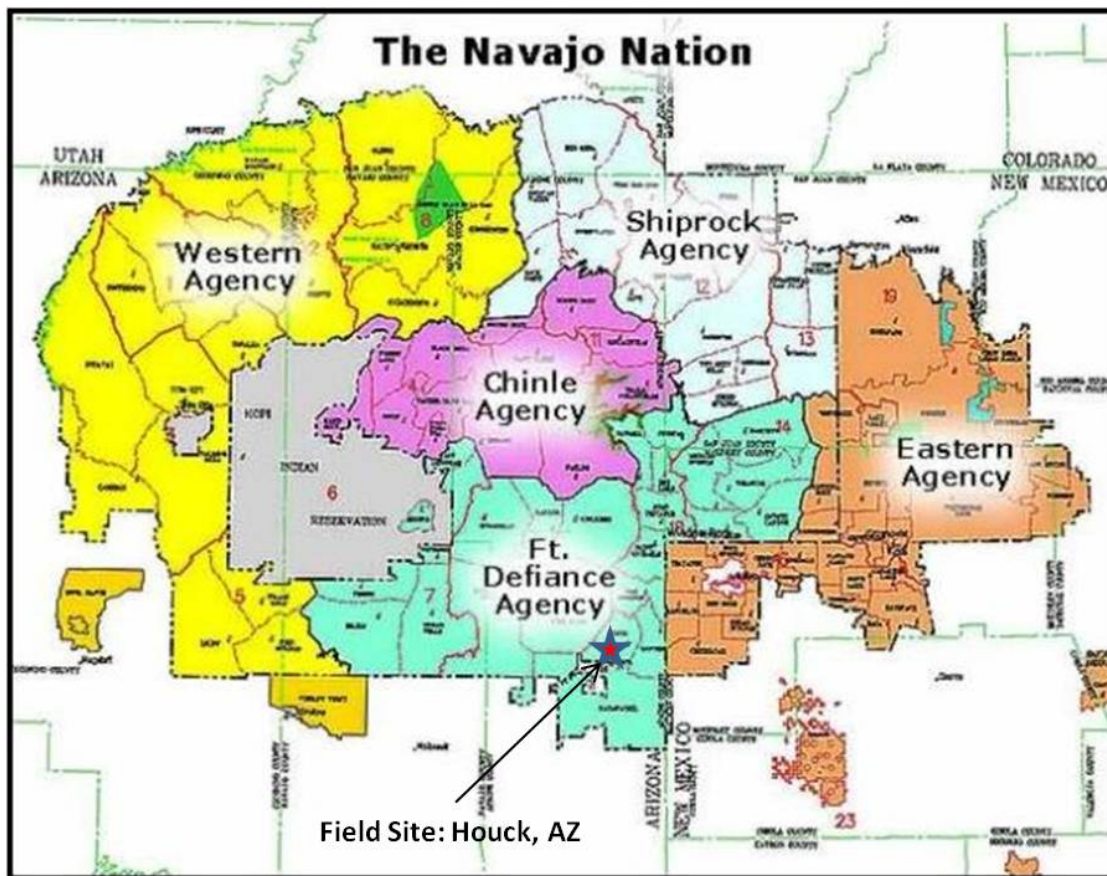


Fig. 3.4 The Navajo Nation Governing Agencies
(Source: <http://www.horsekeeping.com/jewelry/NavajoNation/>)

Field Site - Burntwater, Houck Chapter

The research site is in the rural area of Burntwater (Fig. 3.5) located about 30 minutes' drive along backcountry dirt roads to the north and west of the Houck Chapter House. The general research site area is approximately 37 square miles covering nearly 23,500 acres of rural Colorado Plateau landscape consisting mostly of sage, rabbit brush, piñon and juniper vegetation. It is a sparsely populated area. Fig. 3.5 depicts an approximate distribution of dwelling structures as small dots and a few public locations

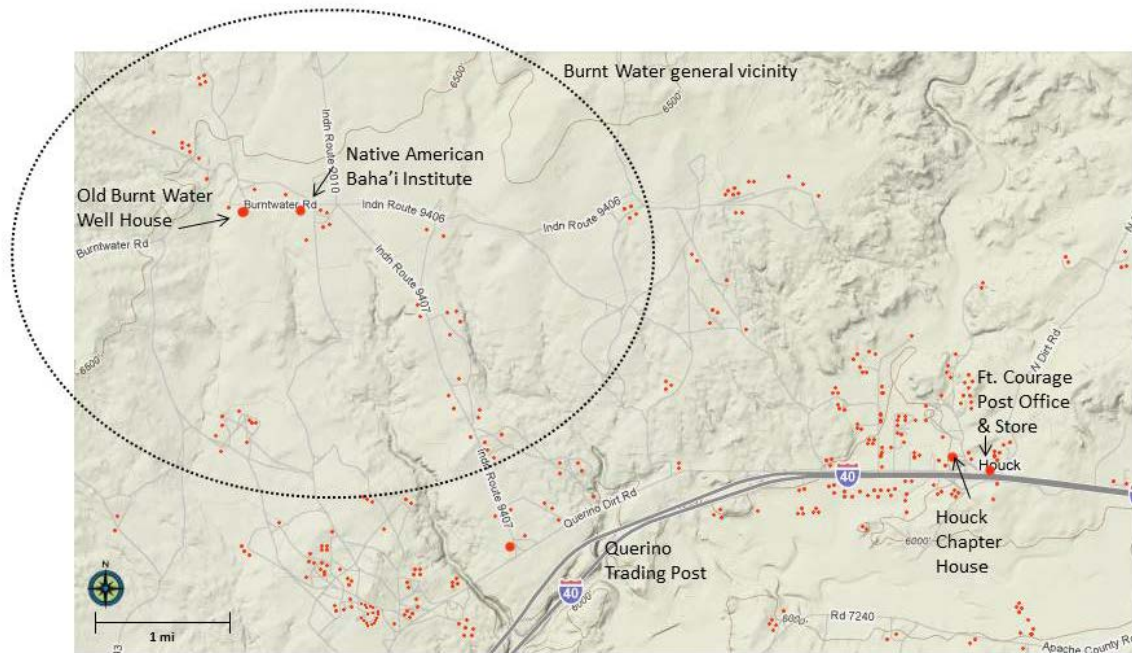


Fig. 3.5 Field Site Area of Burntwater - Houck, Az.

as larger dots. U.S. census data shows an average 3.48 persons per household in this area putting the population in the map region to be roughly 1,000 individuals. There are two main clusters, the Querino housing area to the west of the Querino Trading Post and the town of Houck. The entire population of Houck and surrounding area is comprised mostly of American Indian 96%; with White, Hispanic, Black and Asian making up the remaining 4% (Census-Bureau, 2010). The Houck Chapter can be considered a low income area by most US standards and is below the average of the Navajo Nation earning less than 1% of the total Navajo Nation's salary and wages of which only 283 Houck households in the year 2000 earned an estimated \$23,000 (Table 3.1).

Although Navajos were living in these parts since the early 1700s, it was not until 1934 that this area became part of the Navajo reservation. The rural area of Burntwater took its name after the burning of a central water well-house and trading post during the

Table 3.1 Houck Income & Sources

	Sal & Wage	Self Emp	Int, Dvdn Rntl	Soc Sec	Splmntl Sec	Pub Asst	Retir	Other
Navajo Nation								
# HHlds	33,245	2,702	2,235	9,374	7,394	7,285	4,539	9,612
Amt Inc (\$mil)	\$1,042.8	\$23.5	\$6.1	\$66.0	\$41.9	\$25.0	\$43.8	\$56.1
Inc per hhld	\$31,368	\$8,681	\$2,750	\$7,037	\$5,664	\$3,430	\$9,648	\$5,833
Houck Chapter								
# HHlds	283	32	10	125	48	56	27	69
%NN	0.85%	1.18%	0.45%	1.33%	0.65%	0.77%	0.59%	0.72%
Amt Inc	\$6,522,800	\$377,300	\$12,200	\$91,540	\$185,400	\$125,900	\$140,600	\$199,600
%NN	0.63%	1.61%	0.20%	0.14%	0.44%	0.50%	0.32%	0.36%
Inc per hhld	\$23,049	\$11,791	\$1,220	\$732	\$3,863	\$2,248	\$5,207	\$2,893
%NN	0.00%	0.05%	0.02%	0.00%	0.01%	0.01%	0.01%	0.01%

Source: Census 2000, NN Division of Economic Development

1800s. The Chapter took its name in 1956 after an early trader named John Houck (Houck, 2012). The present Chapter House, seat of the local government, was built in 1963. See Appendix 3.1 for photos of some of the places of interest located on the map in Fig. 3.5.

The Native American Baha’i Institute

A central location and place of work and support during my research was at the Native American Baha’i Institute (NABI). NABI played a key role in enabling me during my visits to the area whether through room and board or offering the use of the facilities for community gatherings and consultations. The local community of Burntwater has gradually come to have great respect for NABI as it has kept its doors open to all who live in or travel through this region. It was instrumental in supplying a deep-water well and making this fresh clean water available to all in the area at no charge. For passers-by, there are shower rooms available for a modest fee. NABI

tirelessly continues to host a free community Thursday dinner for any resident in the area and local travelers passing through in need of a hot meal. It has also been instrumental in collaborating with other residents and local authorities to obtain congressional funding to pave the dirt road leading up to Pine Springs that is often impassable during certain times of the year due to thick mud.

NABI's roots trace back to the 1970s when in 1978 some 60 Native Baha'is and other Baha'i friends (40 of whom were from Navajo-Hopi land) attended the U.S. Baha'i National Convention at the invitation of the National Spiritual Assembly of the Baha'is of the United States. It was here that the news was conveyed to the Convention that they wanted to build a "Bahá'í place" on the Navajo Reservation, and they wanted the Convention to show their support. With the assent of the Convention, two years later, the Burntwater, Arizona property was secured and the institute became manifest. Over the years it has been focused upon various goals. Since 1998, it has been designated a Regional Training Institute by the National Spiritual Assembly. The NABI campus covers 40 acres and currently has five main buildings in addition to residences. Volunteers and staff maintain all facilities on campus. The Prayer Hogan is the most sacred spot on campus. Moving in a clockwise direction, the direction the sun moves is also an important aspect of Navajo tradition. For this reason, a person entering the Prayer Hogan always enters and moves to the left, continuing around in a clockwise direction. Thursday night community devotionals also take place in the Prayer Hogan. These community devotionals are particularly noteworthy because many of the prayers recited on these evenings are in the Navajo language from a variety of traditional and religious beliefs, giving a sense of the strong spiritual nature of the Navajo people. The Big Hogan

is the larger of the two hogan structures on campus. It is used primarily for meals and consists of a large dining area and small kitchen. The Big Hogan is also sometimes used as a gathering place for large programs (NABI, 2012).

BACKGROUND: METHODS USED IN THIS COLLABORATIVE SOCIAL RESEARCH APPROACH

Miles and Huberman (1994, p. 5) point out that “no study conforms exactly to a standard methodology; each one calls for the researcher to bend the methodology to the peculiarities of the setting”. The over arching methodological framework for my research is based on *Collaborative Social Research*, that can incorporate a wide variety of collaborative methods. The specific methods of inquiry and discovery that I have adopted include:

- open-ended exploratory interviews
- open-ended exploratory focus groups
- photovoice
- artvoice
- collaborative consultations and reflection
- mapping (resources, issues, solutions)
- game playing
- agent-based modeling.

Haring (2008) suggests inductive methodology is an appropriate approach to acquiring primary data and results for theoretical model development in which some inductive approaches are not predictive nor do they attempt to predetermine expectations of results. This allows for meanings, perspectives, experiences, perceptions and utilizations to emerge from the participants as part of the participatory process. Such inductive approaches take on a more *soft systems* framework as introduced in Chapter 2.

This also addresses the need for *cultural sensitivity*. As defined by Daniels and Walker (2001, p. 146) “culture is a system of socially created and learned standards for perceiving and acting, shared by members of an identity group”. They further explain how the Native Americans comprise a *high-context culture* by placing great importance on their relationship to the natural world. Haring (2008) points out that the qualitative inquiry process enables story-telling and is a method congruent with the trusted oral tradition long-used in tribal and indigenous societies to pass along key indigenous knowledge—a view point that is supported widely in the readings (see for example: Fikret Berkes, 2009; Fikret Berkes, et al., 2009; Fikret Berkes, et al., 2000).

Qualitative Exploratory Interviews

As noted by Haring (2008) there are few written procedures and mechanisms for conducting qualitative research using focus groups and interviews among Native Americans. The approach I used was semi-structured allowing flexibility to accommodate circumstances and sensitivities of the interviewee as perceived by me. Perhaps most importantly in the context of my research, the exploratory interviews and focus group initiative opened doors to greater participation, helped to establish familiarity with the project and began to foster a foundation of trust between the participants and myself. In so doing it opened up pathways for participants to share ideas and use new concepts in their dialogue in formulating opinions, reactions, and perceptions—a view supported by Haring (2008).

Photovoice and Artvoice

Photovoice is a Participatory Action Research method (Wang et al., 1997), or in my context a collaborative social research method, that integrates Paulo Friere's approach to community problem-solving through critical consciousness; feminist theory; and participatory documentary photography that gives voice to local people (Friere, 1970). Harper (1989) suggests that photography can be used as part of analysis in several ways including a reflexive mode where people respond to pictures of their environments. The *artvoice* method is a variation of the photovoice technique that I introduced as a way to get more of the community involved through arts and crafts. The Navajo have historically favored arts and crafts and continue to express great talent. Navajo art, especially the weaving, is often referred to as "Handiwork of the Gods" (Locke, 2001a, p. 33).

These initiatives are collaborative by design. As pointed out by Wang et. al (1997) regarding photovoice but that I also extend to artvoice, these methods rely on the power of visual images and narratives and see local people as catalysts of change. They are expected to enable participants to record community strengths, weaknesses and concerns; to promote critical dialogue about community issues; to communicate perceptions and knowledge and to reach policy makers. The narrative aspect enables people to reach back into their collective and individual histories to gather knowledge and understanding.

Collaborative Adaptive Capacity Building

Within the PSFA-CACB model approach, other collaborative techniques were incorporated within the CACB framework such as group mapping exercises. This is what is commonly referred to in the field of collaborative research as “mind mapping” that aims to “uncover the power and interests of the actors...that establish an initial collective awareness and solidarity among the team and lead to a common understanding of the case” (Holman, et al., 2007, p. 38). The mapping exercises undertaken in my research, explored below, included resource-mapping, issues-mapping and solutions-mapping. The mapping exercises then lead to the creation of a board game that was used to further explore aspects of the research problem.

Field Specific Credibility, Validation and Truth Building

Lincoln (1985) purports several suggested measures by which I can establish credibility of this project and its findings, keeping in mind that I am not working within the naturalist inquirer paradigm but as a collaborative researcher: 1) by having spent short periods of time in the field for nearly two years I established prolonged activity in a contextual environment. This of course is a subjective and relative measure. I by no means built the capacity of an ethnographer who would have spent years living at the field site. However, to the opposite of this spectrum, my research was not entirely performed from the corridors of a library 500 miles removed from the area of interest; 2) during my periods of field engagement there was a continuity of focus; 3) using various triangulation methods such as contextual and model design verifications, member checks

of interview and focus group notes/transcripts, peer debriefings (committee reviews) and negative case analysis which is another way of saying abductive reasoning. Abductive reasoning is a form of logic used in systems theory thinking where empirical data would suggest a plausible hypothesis knowing at the outset there are other explanations. As more data come in, i.e., in hindsight, the hypothesis is modified or perhaps a record of successive explanatory multiple-alternative hypotheses evolves until one is reached that fits the pattern of observation. This was experienced in the context of my field research through an adaptation of research questions based on an evolution of the research process due to the collaborative discovery process.

In the context of my field research, transferability would constitute a valid measure of trustworthiness—what a “conventionalist” would refer to as external validity such as a statistical confidence limit (Lincoln, 1985, p. 316). Yet, transferability is a difficult matter due to the complexity of whole systems undergoing constant change (Lincoln, 1985). Another conventional measure of trustworthiness comes with reliability as defined through a traditional research lens of stability, consistency and predictability that is often shown through replication, i.e., “if two or more repetitions of essentially similar inquiry processes under essentially similar conditions yield essentially similar findings, the reliability of the inquiry is disputably established” and to apply this standard to qualitative field studies would require acceptance in an assumption of naïve realism (Lincoln, 1985, pp. 298-299). Replicability is a difficult issue for qualitative field research looking at complex social-ecological systems. Due to factors of constant change at temporal and spatial scales it becomes virtually impossible. Hypothetically, if a research project could have perfect replicability it could be said to have perfect validity.

This is what Lincoln (1985) calls the “truth value” of a single tangible reality, an isomorphism, that is in essence an impossible pursuit but nonetheless the “holy grail” of quantitative internal validity measurement. The alternative in qualitative research is a measure of “dependability” through field work yielding a “thick description” of all mundane and unpublished aspects of the project. If a project’s results can be shown to be credible then there should be no further need to establish dependability (Lincoln, 1985, p. 316). Confirmability can be established through triangulation and a reflexive journal are suggested in the absence of a confirmability audit (Lincoln, 1985). The idea of a reflexive journal also allows for more *fallibilistic* self-criticism in the research process (Seale, 1999). Popperian fallibilism is somewhat related but applies to ensuring all hypothesis/research questions being explored are fallible, or what I would say have plausible fallibility, if they are to be considered within the domain of science. Perhaps one of the greatest measures of confirmability in the context of collaborative social research or what Whyte (1991, p. 381) refers to as participatory action research, is that it acts as “a critical safeguard against self-delusion by the researcher and unintentional misleading of colleagues through a rigorous process of checking the facts”.

Another method and its corresponding features of knowledge building and truth verification that is applicable to my research is that of simulation modeling. Agent-based modeling (ABM) is essentially a modeling or simulation of individual autonomous agents within a system or environment. ABM examines the effects of agents on a system as a whole. A key feature of ABM is that it deals with system complexity and enables the modeler to explore this complexity in non-linear ways resulting in outcomes that could not have been seen just through an analysis of the individual agents themselves. Instead,

it is the autonomous interaction of the agents operating within simple heuristic rules under certain assumptions and towards a given objective in their given environment that may give rise to unexpected outcomes—in other words, the whole is greater than the sum of the parts. Emphasis is on the *agents* and not on statistical variables and this approach is in line with social theory in general (E. Smith, et al., 2007; Tubara, et al., 2010).

Explicit models have value because assumptions are made known that give rise to certain outcomes and when the assumptions are altered, the outcomes are altered. It is through such sensitivity analyses where tradeoffs and uncertainties are revealed which models can play a key role in honing in options for decision making (Epstein, 2008).

A particular method of model building is mediated modeling. Van den Belt (2004, p. 3) says that mediated modeling is:

...based on system dynamics thinking but emphasizes the interactive involvement of affected stakeholders in the learning process about the complex system they are in. It allows a group of stakeholders to understand how seemingly small decisions may spiral a system onto an undesirable course. Such understanding provides opportunities to jointly design strategies to abate the negative spiral or to curb a trend into a more positive one.

It is in essence a method of collaborative engagement and is a central application to my research. Inherent in its design, mediated modeling aims for a collaborative team learning experience that elevates the shared level of understanding in a group and fosters a broad and deep level of consensus (van den Belt, 2004, p. 11).

Potential Bias

All research comes with a measure of bias depending on the nature and setting of the research and mine being a field study is no exception. In essence, bias is a tendency to offer a partial perspective at the expense of alternatives, even though those alternatives might be equally valid. This presents a particular problem for field work in general but particularly so for collaborative and participatory field work where the researcher is directly engaged in and influencing the collaborative process—it is simply unavoidable. However, what the researcher can do is try to elaborate on what some of these biases might be so that other researchers can draw on such experiences for possible replicability purposes or perhaps in an attempt to avoid the bias all together to try to come up with different results.

Some of the more obvious influences my presence had in the field were that I am male, I am Caucasian, and I am an older man in my 50s. These are perhaps traits that would impact the way others would see me in their neighborhood more so than how I see them. There were also less know characteristics such as my having grown up as a Baha'i my entire life and how this impacts my worldview and outlook upon the Navajo. How my perception of my fellow human being affects my interaction with them compared to someone with a different philosophical/religious orientation. By the same token, my interest in the environment and how this affects my worldview when working with the Navajo. All these are potential biases one way or the other and although unavoidable in the context of open collaborative fieldwork, they warrant some recognition and discussion.

What perhaps came across at the outset when I first entered the field site was my appearance as a middle-aged white male. Trust was not immediately granted among the Navajo but after the course of nearly two years there was a greater sense of trust and being able to work together than at the beginning. This may have had something to do with my gender, age and race as much as it had to do with my being a stranger. By contrast, when my wife would visit the field site with me she would derive a different response. She is middle aged, female but of Persian descent and has a complexion very similar to a fair skinned Navajo. I noticed the reactions of some of the Navajo when she first visited and it was a very comfortable and relaxed feeling that I did not receive at first but that came about later with time and frequent visits.

Another feature is my belief and worldview as a Baha'i (see Appendix 3.2 for a brief description of the Baha'i Faith). I first came across the Baha'i Faith at the age of nine through my parents while living on Maui, Hawaii. Ever since that early childhood introduction, the holistic and unifying principals of this Faith have been an integral part of my life, shaping and forming my world view.

The reason this maybe a potential source of bias that future researchers might take into account should they have the opportunity to further explore my research method in Houck, Az. is due to the presence of the Native American Baha'i Institute in that area.

It is hard to know in exactly what ways this might have impacted my research but what I can say is that from the outset of my research as expressed in Chapter 1, I had no idea I would actually end up conducting this research on the Navajo Nation much less in the rural community of Burntwater, Az. My initial initiative, had it worked out, would have landed me in East Africa. However, failing to get to Africa I attempted to find an

opportunity on either the Sioux or Ute reservations. As fate would have it, I ended up on the Navajo Nation. Nevertheless, during most of the course of my engagement with the Houck community I made a deliberate attempt not to divulge knowledge of my being a Baha'i. My reasons for this were that I saw this as being irrelevant to my study. In fact it was not until a period shortly before my defense that any of my committee members knew I was a Baha'i—not that it would have made a difference, it is just that I am making the point that my personal beliefs were not being shared openly as my focus was on my research and studies. It was not until one of my committee members asked about it and then suggested I make mention of this as a matter of research interest that I came around to writing about the Baha'i Faith in this dissertation. About mid-way through Phase-II, perhaps because of the collaborative process taking hold where a sense of ease and relaxation among the participants began to emerge, several participants approached me on different occasions, who asked me out of curiosity if I was a Baha'i and how I came to NABI.

Having placed my belief and worldview as a potential source of bias, I would ask the following question to any future reader of this dissertation. How is my being a Baha'i in this context any more a source of bias than for example my being male or white or for that matter a white male Baha'i living in Colorado. How is it that any social researcher can avoid such inherent characteristics and therefore any potential bias on possible research outcomes? In reality it is not possible to be avoided. It is perhaps for this reason that a researcher taking a particular relativistic point of view would say this is why there can be no objective truth in research and no validation of results. However, I take a different post positivist perspective on the matter that requires an engagement of people

and opinion through consultation to get closer to what truth might actually be. It is through this dialogue and consultation that a weaving of opinions and ideas can merge and the more rich and diverse the opinions the deeper the understanding, learning and discovery will become. Therefore, being in the field with a Baha'i worldview in my opinion could only add to the richness of the outcome and discovery.

In the context of my research, surely a female Navajo with traditional beliefs residing in Houck might have an entirely different outcome than what I experienced. However, I do not believe this would make my research less valid, just different. This is perhaps one of the reasons why social research is very difficult to replicate in a Cartesian-Newtonian based physical science framework as discussed above. Therefore, in my humble opinion, all we social researchers may do in the end, where there is potential or known bias, is to make that bias known and leave it to other researchers in the same contextual setting to draw their own conclusions and comparisons. In so doing, they will also be adding to a new layer of understanding through their discovery and thereby building knowledge.

Population Sample

At the outset, the focus population for this participatory exploration during Phase-I and Phase-II was intended to be representative of a balance of female and male, youth, adult and elderly participatory volunteers. The sample size remained small in order to be manageable with intentions to be approximately at 30 participants selected with a *purposive intent* rather than by random process. Qualitative research typically works with small, nonrandom samples of people “nested in their context” (Miles, et al., 1994, p. 27).

The distribution of this small sampling sorted by participatory activity can be discerned in Table 3.2. Represented across all activities, a total of 35 participants (n=35) were

Table 3.2 Participatory Distribution by Phased Activity

Age Grp	Gndr	Ttl Popltn ¹	P-I				P-II				P-III
			Intrvw	FG	PV	AV	Mpng	Gms	FG	Cmnty Gthrng ²	Mdl Rvw
Minor (14-17)	F								7		
	M	1			1				2		
Youth (18-30)	F	8	5	1	4	4			1	1	
	M	4	1			2				3	
Adult (31-50)	F	9	5	3	5	3	6	3	6	15	2
	M	8	5		4	3	2	3	2	5	2
Elder (> 51)	F	3	2	1	2	1	2	1	3	2	
	M	2	1			1	2	2	2	1	
Total		35	19	5	16	14	12	9	14	36	4

¹ n=35 spread over 22 households: not everyone who volunteered participated
² Community gathering involved others outside the total population group
FG: focus group, PV: photovoice, AV: artvoice, Mpng: mapping, Gms: games, Mdl Rvw: model review

involved coming from 22 different households. Across the board, the population group that was most underrepresented were minors and this was due primarily to logistics and difficulty in coordinating parental authorization. I initially set out with an arbitrary cut off point for age distribution ranging from minors 14 – 17; youth 18 – 30; adult 31 -50; and elder 51 and older. However, I found this to be unrealistic and changed the groupings to minors 14 – 17; youth 18 – 25; adult 26 -69; and elder 70 and older. It was not possible to calculate an accurate statistic for median age as many of the participants did not give their age. These individuals were placed into an age group based on a best estimate.

PHASE - I: A PARTICIPATORY COMMUNITY EXPLORATION

Qualitative Exploratory Interviews: One-on-One and Focus Group

One of the primary objectives of this part of the research was to begin a process of introducing the participants to the project, introducing them to me and me to them. Another objective was for me to gain an understanding, a baseline, as to the participant's understanding and way of thinking about the subject matter presented in the questionnaires. Responses to the one-on-one interviews and focus group open-ended questions were varied and are presented in the next section. There were fourteen questions with a participation pool of 19 for the interviews with some of the interviews conducted in a home with the whole family participating. The actual number of direct respondents was 15 (n=15) giving a total of 210 possible responses. The focus group (FG) consisted of twenty-two questions with a participation pool of 5 (n=5). For both methods, all questions were in categories concerning the environment, energy, entrepreneurial solutions and capacity building.

Results and Learnings

EXPLORATORY INTERVIEW RESPONSES

Numbers correspond to actual respondents and can be traced through the responses. NB: respondent #15 is not Native American but has been living in the Navajo community for decades and is married to a Navajo.

ENVIRONMENT

What does “local environment” mean to you?

- 1 Don't know / explain?
- 2 From where you are from around everything surrounding where you live
- 3 Lots of things, people look at it differently everywhere you go, beer cans, bottles, some places see people pick up trash and pick up community
- 4 Surrounding area of community, what's happening in the environment
- 5 Our surroundings
- 6 The community of Pine Springs, however the amount of people living, what is it lacking, electricity, water, transportation, what do people want, can the Tribe help us?
- 7 The land we live on and the air we breathe above that land. Everything that took place there and is taking place there. Uranium mines live close to I-40, can smell traffic from in valley. In winter see traffic 24 hours day and night
- 8 Don't know
- 9 Cleanliness, letting the animals run free in the woods, beauty, trash picked up. No dumping in woods, around good environment good clean land, good roads, trimming dying branches from trees
- 10 Traditional teachings talk about earth, air, water, fire and living animals including the human being, beauty and order
- 11 [no response]
- 12 Everything - could be roads, water, electricity to power, energy. A community where there is a level of individuals coming together, for meetings to consult on community needs and problems, with administration and organization. Working together in unity to make our environment livable in a beautiful way and it has to do with property, the home, the Navajo way of life, center of creativity, place of education, love, spiritual ceremonies of healing. It has to do with physical as well as our mentality of people and spirituality
- 13 Clean air, no pollution, clean energy
- 14 I guess local environment means to me where we live, certainly NABI campus and surrounding areas has been our local environment. But I need to think of not...I am originally from Ft Defiance AZ from the Defiance Plateau and you know when I talk about local environment in that instance it would be those areas that I am most familiar with. Those areas that I walked on became familiar with, the corn fields, where our sheep grazed where horse corral was, that's all local to me.
- 15 In that context, [respondent #14] was talking about herself and the earth and the things that surround her physically. That reminds me of Chief Seattle's remarks where he says something about to the affect the earth is not ours, we belong to the earth and we need to take care of the earth if we are to be sustained and so what's important about the local environment that [respondent #14] was talking about is what's our relationship to the local environment. In a since that's at the core of it because there may have been a time a long time ago when we were undeveloped as creatures and the environment was what it was and now that we are here how can we contribute to the well being and the development of that environment. Talking about a small part of the community – not the whole earth, that is not

what comes to mind with local environment. Something the people in the community can focus on, something they can come to an agreement about and form some plan of action about.

What do you think is important about your local environment?

- 1 Roads, especially during rains, dusty when wind blows, especially for the baby
- 2 Helping the old people and the trash that surrounds the area
- 3 People, leaders need to get with people and do something about it. Only time they do that is during elections. People tried to close the bar but under the table with local sheriff
- 4 Should be good in working together to make it clean, have respect, to have clean ways ... friendship
- 5 Clean environment, clean air, quiet, not lot of commotion
- 6 Safety, more information given to the community. May have health problems. Local information from Chapters. More information. Say – give flu shots ahead of time to be prepared, not last minute. They always say I didn't know that. Through the radio
- 7 Help from government, lack of water. Help supposed to be getting from local government, help not coming. Water to bring out this way. Water, a local line is not clean from red clay. Trace of radon and uranium in it. Windblown sands out to contaminate water and people get sick with live disease and skin growth of people around here, 25 years and back
- 8 Don't know
- 9 Most important is clean air and mother earth, clean water, not overgrazing the grass, fire prevention
- 10 Protection of mother earth, water and grass. Careless, things get dumped and burned and goes to the air, goes to the water and ground. Right at our back door can see the fire; a lot of people have asthma and health problems. Need to empty trash in proper place
- 11 [no response]
- 12 Most important is coming from Navajo Country. The significance of the spirit. We are spiritual beings we are created spiritually, one with Mother Nature and mother earth, one with the environment and the universe
- 13 Want to be free of trash, clean air, clean energy, water, soil, especially water because that is our life

What does “sustainable development” mean to you?

- 1 First time hearing this
- 2 Building a stronger community
- 3 Don't know
- 4 To sustain, to keep it happening
- 5 Not sure what sustainable means
- 6 Survival? Don't know
- 7 Don't know...forefathers planted and had livestock and now we depend on government handouts and go to the store and foods affect our health and

- vegetables with pesticides. Here nonexistent to have sustainable ways, not so much livestock
- 8 Don't know
 - 9 [at first did not know until spouse responded] Building sustainably with materials, picking up rocks that are available, proper places to get logs to be used properly, ponderosa pine, sand, dirt material
 - 10 Example would be sustainable, environmentally friendly construction, recycling parts of buildings torn down from winterization
 - 11 [no response]
 - 12 Many things we develop in the community has to be sustained with different materials such as funds and peoples commitment to sustain. An individual level has to be commitment with unity and oneness. Some development is large and takes a whole country to keep that development sustainable
 - 13 Something that has never been accomplished
 - 14 I think an example of sustainable development is so different from what we were thinking about working at the earth, something that keeps on moving...an example of sustainable development to me is when a medicine man passes his medicine bundle to his son or his daughter and he or she keeps the chance going and it heals anyone that comes in contact with him that needs their services. The medicine bundle may have had a history of 2 to 3 hundred years. I know in my case I am only familiar with what my mother has passed on to us and that has been in the family for 200 years.
 - 15 So he's the keeper, just as we are the keepers of the earth, the keepers of the wellness. Sustainable development means something to me where the friends and the local community can together perpetuate through some actions, through prudent decisions and activities to maintain the wellness and the health and the well being of not only the physical environment but their own human environment.

Can you give an example of a community plan or action that has occurred that you consider contributes to a more sustainable environment? Please explain why.

- 1 First time hearing of this
- 2 Give out free wood and coal to elders because maybe they have no one to give them wood, they are disabled, can't move
- 3 Took picture behind the Chapter house of the big dam with irrigation ditch – it's an old dam with valves... Should be a Houck community effort to reclaim the dam....
- 4 The community tries to have chapter house meetings to plan housing development, helping people....
- 5 Road being surveyed
- 6 One thing we don't have is communication. Like at the senior center. Radio would be best. Don't know where to get information. Gathering place like Pine Springs doesn't have a Chapter House
- 7 Use to only plant corn crops, drought over 20 years, no rainfall or snow. When younger would have 3 to 4 inches of rain, now it is just dry
- 8 Don't know

- 9 Tried to close down the open dump. The tribe closed the large one. Tribe doesn't have the capacity. School has a dumpster but is limited. Pine Springs does not have a Chapter House. Pine Springs has a 501c association and ____ is the new president and ____ is the new VP. Need to get a development guest. ____ has offered and is with the council of tribal government in NM. Pine Springs and Oak Springs have ethical challenges, funding is not available
- 10 [no response]
- 11 [no response]
- 12 No
- 13 Community land use, planning committee was just certified and can move forward to develop some economics for the community

ENERGY

What does "energy" mean to you?

- 1 Company needs energy. Something needed to move around. When I drink my cup of coffee
- 2 Having the power, the power to do about anything, like helping people
- 3 Don't know
- 4 When eat, you get hungry need to eat. Gas, different people vehicles. House warm, my son hauls wood to help
- 5 Being with ourselves, having certain ideas, being outspoken, something that is being developed within the community
- 6 Electrical, Transportation, being healthy
- 7 Lucky to be close to I-40 to get lights. Way out to the reservation they have to pay to run a line. Need a water line, don't have water yet. Government giving out water rights. People in other parts of Apache County getting rights but not coming to here
- 8 Don't know
- 9 Our capacity, acting and doing something, different kinds of energy around here is wind and solar that would be sufficient and outstanding
- 10 What energy helps us to have energy, using environmental resources to build with
- 11 [no response]
- 12 Power – like electricity, water, different things that keep us alive. Manpower and resources
- 13 What we need to give, what is holding up would move forth with fuel and all that

What does "renewable energy" mean to you?

- 1 Don't know/explain
- 2 Renewing, getting new ideas of how to get new energy
- 3 Don't know
- 4 Means to renew it
- 5 Something we can use from the environment
- 6 More improvement in health care, equipment wise. Health care should come to homes to tell sick how to use oxygen. I'm finding out my brother has to go on oxygen and don't know anything about it

- 7 Renewable energy, talks about wind power for electricity to be around Arizona
- 8 Don't know
- 9 Solar, wind
- 10 [no response]
- 11 [no response]
- 12 Development of energy that needs to be renewed such as instead of fossil fuel for energy that is causing lots of pollution. Renewing energy is to have solar power, use the stream energy
- 13 I guess some of the plants can renew the energy, would have to burn it and recycle it almost. Yesterday at committee meeting we were talking about the shutting down of 3 power plants and keeping 2 going.
- 14 I always think or had the idea in mind that we need to recycle all these beer cans and soda cans and do something with them, get the money and use that money for other energy explorations. I know one that really comes to mind is wind, the wind energy, that is something, that at the whim of nature that we can use it. As much as we want.
- 15 Renewable energy strikes me as the kind of energy that doesn't distract from or destroy or make any less the environment from that it is a part. For example, and I do not know all the forms but I would love to know them and I think the community would love to know them too but some of common popular ones are solar energy, or even some bio products waste or just because of its growth and abundance it is available to be converted to be used into other uses including energy, even in fact trash. What society is throwing away as trash can be reused in some kind of ways and as a source of energy.

Can you give some examples of renewable energy?

- 1 Don't know
- 2 Buying a new stove instead of using wood, get out of the car and walk
- 3 Don't know
- 4 Clean air, clean energy
- 5 Like NABI is renewable energy, lots of people benefit from NABI and use it all the time
- 6 Don't know
- 7 Some are dealing with solar systems. In Houck area, putting up cellular phone towers, that is new
- 8 Don't know
- 9 Used to have wind mills, now have water pumps
- 10 [no response]
- 11 [no response]
- 12 One example is to teach children science so they will be able to understand how to renew our energy out of the future. To have children acquire science and technology
- 13 Clean refineries, reuse it in some way so don't have to smell the odor

Describe any local examples of renewable energy you have seen in your community.

- 1 Don't know

- 2 Seen some people walking most of the time, until recently got a truck now we use gas for energy
- 3 Don't know
- 4 Sand plant – Arizona silica sand
- 5 Chapter House – think it is renewable energy, keep people informed of what goes on
- 6 Don't know
- 7 [no response recorded]
- 8 Don't know
- 9 Don't have anything
- 10 [no response]
- 11 [no response]
- 12 No
- 13 Not sure if sand plant qualifies

ENTREPRENEURIAL SOLUTIONS

In your own way, describe what an entrepreneur is.

- 1 Don't know
- 2 I don't even know what that is
- 3 Don't know
- 4 [no response recorded]
- 5 Don't know
- 6 Don't know [explained]
- 7 Don't know
- 8 Don't know
- 9 Someone who is capable of many tasks, many ways to bring community in a healthy way
- 10 [no response]
- 11 To have coffee/tea and a book shop with good health
- 12 Don't know
- 13 Don't remember
- 14 I think an entrepreneur is one who is familiar with business and can be a business man
- 15 The notion of entrepreneurship has been around I think for a long time. It may not be described in those ways. A lot of people have taken it upon themselves to sustain themselves in some way by an activity that is good for the community through which they can through barter, trade or sale accomplish something with elements of the environment or through their surroundings. It could be food preparation, it could be other kind of things

What problems in your community could a local entrepreneur fix?

- 1 Develop water pipes for the community
- 2 No gas for car, buy them gas
- 3 Like youth center, needs to be away from the bars. Only to close the bar. Used to be a substance abuse coordinator in building then wellness coordinator. Nobody

wants to volunteer. Me, I did a lot of volunteer. Asked to do bingo and family fun night

- 4 [no response recorded]
- 5 Don't know
- 6 Small business loans, visiting people to see their problem what to fix. Availability of loan so can sell goods, can repay
- 7 Few, cattlemen graze cattle. The other day I heard on the radio...down payment get ride to Flagstaff
- 8 Don't know
- 9 Bring in exercise for families as a pow-wow dancers at schools with basket ball for youth. After school hours for youth development
- 10 [no response]
- 11 [no response]
- 12 My idea of a youth Center and for children
- 13 The gas stations
- 14 ...and what problems can a business man in our community fix, I think someone ought to go into recycling and the trash pickup
- 15 Now with regard to the environment itself in other kinds of ways, there could well be and someone needs to put pencil to paper to this and think some of the things through. Some of the choices in this community, some individuals or a small group of individuals could organize to take products, even waste products that are here in abundance and convert them into employment for themselves, profitability for the enterprise and a service to the community. It seems like there are some things that would fit into that matrix and satisfy all those requirements and protect the environment if not improve it at the same time.

What, in your opinion, is a “business coop”?

- 1 To listen, sit still
- 2 Cooperating with everyone else, getting together, talking with others, don't even Know
- 3 Don't know
- 4 Yes ...
- 5 Don't know
- 6 Guy going to trading post and selling things to others
- 7 Don't know
- 8 Don't know
- 9 [no response]
- 10 Like a food coop, bring in supplies, extra food from farming. Farming is inevitable for Navajo nation. Need a means for local producers, distribution and storage
- 11 [no response]
- 12 A long time ago was part of development on the reservation that has to do with community, people of the community. Group of people coming together to start a coop like a store or a trading post to sell, a local store. Effort by group of people, benefits go back if it is voluntary but if for profit (\$s) the benefits go back to the coop to sustain itself

- 13 Heard it sometimes in the paper
- 14 ...and the business coop is where everyone helps and its on a volunteer basis....

Do you think your community could benefit from a business cooperative?

- 1 Put announcement on the radio, to have meetings, things to do, to get business going
- 2 Trying to understand
- 3 Don't know [after explanation] Stores and business have red tape and don't want to get together and help each other.
- 4 Didn't want to work together, want to be independent
- 5 Yes
- 6 Yes, trying to recruit Pine Springs to put a building up and to contribute as a group
- 7 Nobody runs business, it is [local business owners named]
- 8 [no response recorded]
- 9 Yes
- 10 Yes
- 11 Yes
- 12 Don't know because most people have a place to go to get what they need, like in Gallup. Have local grocery stores, gas stations. To develop a youth center
- 13 Yes because here we have 4 neighboring Chapter houses

CAPACITY BUILDING

What, in your words is "individual capacity building"?

- 1 Draw a map, start out what to do like a puzzle
- 2 Ask questions to someone who might know the answers
- 3 [no recorded response]
- 4 How many people that can be in a building
- 5 Constructed – could mean people being more involved in the community, everyone has capacity to think big but nobody goes forth
- 6 Regroup with safe sound building
- 7 Don't know
- 8 Don't know
- 9 Unity, writing a study of all Faiths, culture sharing, looking at the good and bad helps our actions. Beautiful birds or trash or grass, eagles with tears in their eyes
- 10 Navajo culture, education, As we work on actual projects on the environment that helps us to build our capacity
- 11 [no response]
- 12 Where an individual is trained to get the knowledge to understand the self power and to have the ability to development and the leadership. To acquire infrastructure and to recognize things that need to be accomplished in the country
- 13 Chapter House has a capacity of 200 people to utilize the meeting room
- 14 Individual capacity building where you see these individual strengths of an individual and build on that and you can do that through encouragement, training, through...

How does someone build capacity?

- 1 I tried to make a map – to go to school then finish school
- 2 When asked math teacher how to do a problem and he explained the hard and easy way like with fingers and using a times table
- 3 It's hard around here. Different from big cities. Have leaders but it is hard to reach them. May be in 20 years there will be something but not right now
- 4 [no response recorded]
- 5 To be open, to be outspoken, friendly
- 6 Don't know
- 7 [no response recorded]
- 8 [no response recorded]
- 9 Study and action to put study into action
- 10 Bringing up children in difficulty
- 11 [no response]
- 12 First is we must understand we are spiritual beings and we have an understanding that we have been created by the Great Spirit, the Creator ...at how to be a true human being. If one understands and builds spiritual capacity it is easier to understand and build physical capacity that has to do with living the life that is with dignity and honorability. Take care of myself and the community
- 13 Start something like a small business and add to it
- 14 An example of individual capacity building is one where the jr youth in this area have participated in the Ruhi courses and as a result of being exposed to words that they are not totally familiar with they have increased their capacity and their parents have told us that their grades have gone up and they are more self assured in presenting their ideas so to me the link between Ruhi and capacity building is fantastic and I am
- 15 I was going to say that you build capacity in a variety of ways, one is that you develop a shared vision of what it is you might want to aspire to, then you understand what it is the individuals need to acquire to accomplish that, there are probably elements of training to help people achieve that level of the extra capacity that they perhaps already have and then some system of coordination and cooperation and systematization that helps those capacities be directed to the object of their attention. And then apply it to the needs to the community.

FOCUS GROUP RESPONSES

ENVIRONMENT

1. Show of hands – who knows what the word environment means?
 - 2 of 5
2. Volunteer - What is environment?
 - Surrounding earth, plants, trees, animals, objects, community functions, people in the community
3. Show of hands - who thinks the environment, is important to your local community?

- 4 of 5
- 4. Volunteer - list 3 things you think are important about the local environment?
 - Water, air, heat
- 5. Show of hands – who knows what “sustainable development”, is?
 - 1 of 5
- 6. Show of hands - who thinks sustainable development, is a good thing for your local community?
 - 5 of 5
- 7. Volunteer – name one example of sustainable development in your community?
 - Water, long term

ENERGY

1. Show of hands – who knows what “energy”, is?
 - 3 of 5
2. Volunteer - can you give 3 examples of energy?
 - Resources, materials, solar energy, food, gas, coal
3. Show of hands - what is “renewable energy”?
 - 0 of 5, verbal response was “recycling”
4. Volunteer - can you give 3 examples of renewable energy?
 - Solar energy, heater to generate electricity, wind
5. Show of hands – can you give an example of renewable energy in your local community?
 - 0 of 5

ENTREPRENEURIAL SOLUTIONS

1. Show of hands – who knows what an entrepreneur is?
 - 0 of 5
2. Show of hands – how many think a local entrepreneur could fix broken problems in this community?
 - 0 of 5
3. Volunteer - what problem in your community could a local entrepreneur fix?
 - [response is for both Q2 and Q3] water wells to be fixed, building casinos, home improvement business, water wells to be dug, bathrooms
4. Show of hands – who knows what a “business coop” is?
 - 0 of 5, verbal response, business sharing
5. Show of hands – how many think your community could benefit from a business cooperative?
 - Yes, w/strong backbone needed
6. Volunteer – how might a business coop work in the community?
 - [no response]

CAPACITY BUILDING

1. Show of hands – who knows what “individual capacity building” means?
 - 0 of 5
2. Show of hands – how many think individual capacity building is important to a community?

- 5 of 5
- 3. Show of hands – how many know how to go about building individual capacity?
 - 0 of 5, team work, cooperation, involvement
- 4. Volunteer – how can we build capacity in this community?
 - [no response]

Of the 210 potential interview responses, 65 (31%) came back as either a non-response or a “don’t know” with the majority of these coming from the entrepreneurial and capacity building sections. However, as respondent #15 commented, “The notion of entrepreneurship has been around I think for a long time. It may not be described in those ways” was very observant. In fact, in the instances where there was confusion or no response, I proceeded to share an explanation or clarifications that subsequently lead to some response in some of the cases. For the focus group, of the total questions asked, nine (23%) came back with no response or a no show of hands, again indicating confusion or lack of knowledge and again the most occurrences of this were in the entrepreneurship and capacity building questions. Overall, this is a clear indication that the language used of “entrepreneurship” and “capacity building” presented these concepts in ways that were not easily discernible at the outset but it could not be said there was a lack of understanding as to the concepts themselves once the language barrier was cleared up.

I felt this part of Phase-I was a success based on the expectations set that were to establish an introductory dialogue among several of the participants and to use this forum as a way to introduce ourselves to each other. This also allowed an opportunity to discuss the topics at hand and have a conversation about these general themes, including the scope and nature of the exploration. This practice helped to establish a level of trust and

confidence at the early stages that was not there at first and that continued to grow through Phase-I as more and more encounters were made.

I was particularly struck by some of the comments to the interview questions and conversations outside the formal interviews such as on the concept of *energy*. Coming from my academic perspective where I have been studying renewable and fossil-based energy forms I had a predetermined view on what energy was and this was soon broadened when several of the responses related energy to human food consumption and having enough food to be able to get through the day. This was a form of energy that was accurate. However, it had never entered my mind as an energy concept during this part of the research. Food as a source of energy is vital to all humans but where it is not in abundance, it becomes central to ones thinking which I just took for granted. It is through this dialogue and consultation that a weaving of opinions and ideas had merged giving rise to a deeper understanding and discovery of knowledge and truth.

Several learnings on a practical level also came to me out of this as well, the least of which is knowing how challenging even the simplest of elicitation methods can be when conducted in the field. I realized this early on during my first interview using the original interview sheet that proved to be too long and too complicated. Making field modifications on the go, I simplified the interview into a short version and used that consistently for the remainder of the interviews. In hindsight I can now use this knowledge to conduct even better field interviews knowing that there needs to be a balance between simplicity and being able to cover the ground required.

Photovoice and Artvoice

A collaborative method used in Phase-I involved photography, art and storytelling known as photovoice and artvoice. These are media where expressions can engender a sense of pride, self-esteem and ownership among its practitioners while also empowering effective communication of an idea or concept. Through the photovoice, artvoice, and consultation group engagements, community members found new avenues of communication and ways of expressing their ideas, emotions and opinions (positive or negative) about their local community. It also opened up new ways of learning and knowledge sharing. These initiatives are collaborative in nature and were taken up by the Burntwater/Houck residents with great enthusiasm. Unlike other studies (Wang, et al., 1997) there was little need to spend much time in formal training on the use of cameras or on the instruction of art.

Eighteen individuals were invited to participate (9 photovoice and 9 artvoice), each given either an inexpensive digital camera or modest art supply kit of equal monetary value of about \$60 each. The participants were asked to photograph or express through art, aspects of their livelihoods that relate in any way to their local environment and energy needs and to express in writing or story form the significance of the photo they took or the art they created. After all the works were collected a community gathering was held to share the results and outcomes of this Phase-I and that culminated in two separate random raffle drawings for third, second and first place for the photo and art categories. The raffle drawings were intentionally designed so as not to create disunity or conflict that might have arisen if a subjective selection process were used through a

judging panel as well as to convey the message that all of the artistic work and narratives were equally appreciated regardless of the skill involved.

Results

The primary objective for using these two methods was to elicit true community concerns from the participants. A wide variety of responses came back including topics on illegal trash dumping, wayward youth, graffiti around the area, electricity, water, the roads and fear of losing the use of the Navajo language. Despite a pre-focused slanting towards renewable energy introduced through the interviews and focus groups, energy or renewable energy were not at the top of the list of concerns as I was perhaps anticipating. What came through in the visuals and corresponding narratives was a concern for the environment and all the illegal trash that is being dumped on the landscape.

Below are results from the application of the photovoice and artvoice method. The narratives are not edited and are presented as given to me either in writing or transcribed from audio recordings.

EXHIBITS: PHOTOVOICE



I feel pain.
I am crying.
I feel sadness.
I feel anger.
I am longing to throw the old, rusted, used car into your house.
I am disgusted with you humans.
I feel timid and helpless.
I have been rejected by the people.
Remember how the people used to take care of me.
Sing and sleep on my rocks, sheep would groom my grass.
I wish the people would plant grass, corn, potatoes,
carrots and green beans.
Have ceremonies for rain to wash me.
Please remove the tires, trash and old cars,
so I can return to my original beauty.

Fig. 3.6 I am the Canyon



“My Grandmother once said, “People today are losing the connection with the earth. People need to take their shoes off and connect with the earth” So this is exactly what I did one day for a hike. I was hiking down a river bed with a friend when I took off my shoes and socks. We hiked the stream bed until it became a river bed, and then it turned into a canyon. There was no water this time of year. At the mouth of the canyon there was a tall bridge, that cars and trucks drive on. I climbed up to the top of the bridge. It was long way up and I was a little scared. I made my way to the side of the bridge where the bridge met the canyon wall. I was under the bridge when an irregular shape caught my eye. I took a picture of it. It was wonderful being around nature walking down the canyon, and not so wonderful finding a used syringe.”

Fig. 3.7 Syringe



“Dumping trash along the side of the road is not good for our community. Houck community chapter recently established a community trash dumping site located at the Chapter House where people can take their trash for a small amount fee. Only a few people utilize the facility. Many still continue dumping in undesignated areas. This problem is unsafe for the community including domestic livestock. Community Education is needed with the help of Environmental Health Protection Facilities. By: A Concerned Community Member”

Fig. 3.8 Illegal Dumping



"OUR COMMUNITY IS BLESSED WITH AN ARRAY OF ABUNDANT RESOURCES INCLUDING THE VAST SKY, BOUNTIFUL SUNLIGHT, A LIVING FOREST, GREEN SHRUBS AND PLANTS, LAND AND ROOM ENOUGH, AND ACCESS TO THE FREEWAY WHILE PRESERVING OUR BACK ROADS AND FIREWOOD TRAILS, WITH BEAUTY EVERYWHERE ...



... BUT WE ALSO HAVE POLLUTION, WASTE, TRASH-DUMPING, AND DISCARDED REMNANT VEHICLES ALL ACROSS THE LAND. WE SEEM TO ABUSE THE VERY LAND WE INHABIT. BECAUSE WE ARE GUESTS UPON THE LAND WE NEED TO TAKE CARE OF IT SO IT CAN TAKE CARE OF US AND OUR CHILDREN'S CHILDREN."

Fig. 3.9 Our Community is Blessed



I attended school at this place started at nine years of age. I also was Baptised at St. Domanic Hall catholic church in Fort Defiance, Arizona when I was very sick at 4 years old. My grand father ...who donated the land the church was situated on at Houck in 1932...he died on July 27, 1958 and is buried on the property also my grandmother who was 100 years old at her death....

Fig. 3.10 The Reason Why I Treasure this Catholic Church



“This big teapot should be one of nature’s wonders of the world. People driving through tourists should, if they know about it in books, we should have people stopping by and be taking pictures of this giant magnificent teapot. It is located about 3-4 miles North of Lupton/Window Rock Exit, on your way to Gallup before you hit the AZ NM state line, and from East, from Manuelito 4-5 miles to the state line again, and go North on your first exit – Lupton/Window Rock. I myself have always heard it through my mom mostly, that somehow through the winds it was formed like that. So by chance, you ever get craving for that delicious cup of coffee, or the wild tea, that we call Navajo tee, help yourself and enjoy a giant cup. Right now is a good time for coffee or T. I just know this is one of Gods greatest manifestations.”

Fig. 3.11 The Big TEAPOT



“I did a subject on ah, about the dam that’s located north of ah, Houck chapter about 2 mile. I was talkin to one of the elderly person, back then they were young people and how they started they built a small dam across usin a horse, they go around in circle and with like a, kind of like a big shovel they shovel it out and they dump it on the, on the dam and that’s how they built, that’s how that dam was formed. And later, twice, I think twice I heard that water went over and then they redo it, they keep redoing it, using the horse to shovel the dirt out of there to clean it out. And then later some years another years down the job corps came down and job corps built a bigger dam and then this water valve where you open to irrigate, for the irrigation for the community lower valley and they did that and then still water keep spilling out back then. There used to be water running all the time like a river and water kept spilling up and it went over again, it went over again and this time it just let it went over and break out the dam and it just went runnin through and nobody never bother it and they been trying to, our leaders today they were sayin they were been trying to contact those people that built the dam, the job corps.”

Fig. 3.12 Houck Dam



“This is my backyard. Back in February of this year we got our water and this is where the leach line is at and during the summer I planted some squash and some corn. I was just messing around with it because I know the Mormons, I know that they used to plant corn in their leach line area... then I thought well maybe let me try it but then I kind of thought it was dirty at the time but then I thought well the leach line we have not used the water a lot so how could it be dirty I thought, so one morning I went over there and I planted 10 squash that was very deep, kind of like sitting on top and then I put in about 40 trundles of corn in there and out of all that I only got I think 6 or 7 corn, not very big ...it grew like about maybe up to my neck is how tall it got and as it was growing and growing ... and it got 6 ears of corn from there and then ... we got a long one pretty long but just with teeth here and there. It was pretty good but we didn't eat it or anything but I went back about, I kept checking on it and then it was kind of kept getting dried up so I went there one morning I mean one afternoon and I brought some corn in, took it inside and I dehusked the corns and they were all pretty long and we boiled them so we had like about 4 or 5 ears of corn that we had...with butter on them it was really good, yes! But I am going to try harder this year, next year. May be I will have bigger and more corn.”

Fig. 3.13 My Garden



“This is my story about this Wagon you see in this picture. I took this picture because it amazes me, how it’s built. Front to back it has seating to bounce up and down. Four very thin tire – like wheels (wheel of fortune) j/k HA HA. A place where you could put your goodies – such as a load of wood; a bale or two of hay; may be even all ten of your children ... oh and a small wooden tail gate. OK – back to amazing – about 85% is made from wood and 15% is metal. Our modern day vehicle can travel @ a speed of 75 mph and travel 1 to 2 minute every mile. So back in the day a wagon traveled 20 to 25 minutes per mile. An accident was hardly ever heard of – wasn’t that a good thing, something good or what!!! I always wonder, if people were always late ofr appts. / dates / mtgs. Haha – I don’t know if its only me but I’m always late. NEVER ON TIME. That my story, and sticking to it.”

Fig. 3.14 The Wagon



“This is the place where I and my son ... live at in ... have been here for about 9 months. We have gotten too comfortable here, not hauling water or chopping wood for heat. But we still plan to go back to the reservation to our hogan. We could walk for exercise and to the Post Office and stores and our senior citizens center to eat sometimes. Then to our local Valley High school to see a game or other events that take place there. Try to support the high school for their annual trips wherever.”

Fig. 3.15 My Place

EXHIBITS: ARTVOICE



“In this picture which you see is how it would look if people didn’t cut down tree’s or even do Arsons, or forest fires, but now look outside at night it look’s awful the sky is nice but you can’t see the stars with smoky clouds and the trees all cut down like hot it is very night. It would look as nice as this picture if it was stopped long ago.”

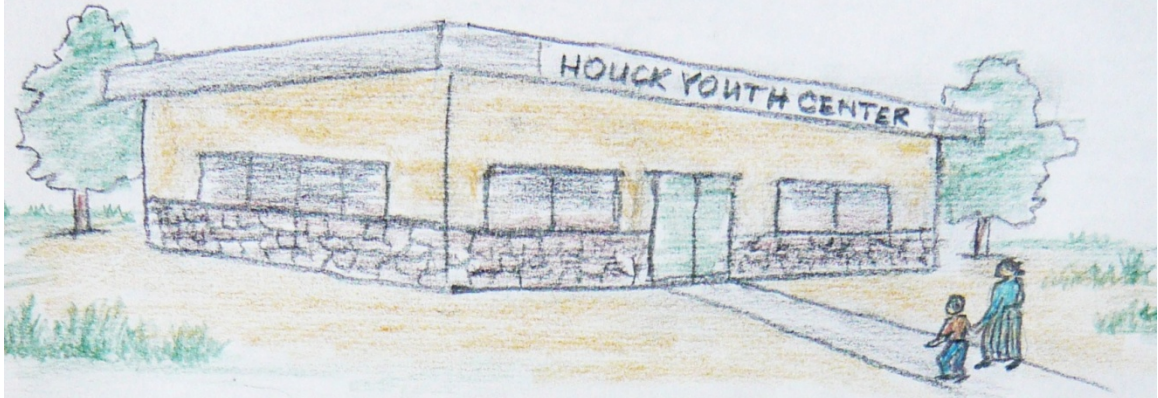
Fig. 3.16 The Beautiful Night Sky



“... and this one I draw is a factory that, that is polluting our lakes around the United States and around the world and factories too, they do that alot. I see these stuff on movies on the news and every where. Like the movie Avatar, I see a lot of stuff where they do on the earth, on their land too. And everything where they do to mother earth they are destroying the air, and they’re destroyin the land too, and their destroying the animals where we see on this earth and this is how we see alot of stuff going on on earth.”

Fig. 3.17 People Dumping Garbage

YOUTH CENTER for Children, Jr. Youth and Youth



Establishment and Operation

Receive Funds from Foundations and Government for the Building, Equipment and Operation. A Committee, chosen by the Chapter, will be responsible for Construction and Operation.

Operation and Instructions

- Arts: drawing, painting, silversmithing, weaving, etc.
- Navajo culture and traditional values (K'é)
- Language
- History and legends
- Work with parents and community
- Hike and camping
- Self-concept
- Others

Instructors for various activities will mostly be from the local community. Examples: An art teacher will teach once a week for two or three hours. Activities will be supervised by an experienced person chosen by the Committee.

Fig. 3.18 Houck Youth Center



“The land is precious to us, we love our horses, we care for them & they in turn care for us. We worry about the over grazing, some of us have learned in school that we can hold back part of the land, and use this for growing alfalfa for the future.when one side of a fenced in area is used we can move them to the other side. before it turns to desert, as it sadly has, in many areas of our Reservation. We also think of energy efficient construction.the use of alternative materials, like 'straw bale', for our hogan's- (traditional round houses, used for elders who prefer them to large home. that take so much more to heat & cool.) We also think of using it for winterizing our homes. such as trailers & pre-fab homes. Also putting away the trash properly so the animals are not sickened or hurt by it. We could make room for them to graze, where it is safe with no trash around.safe for them to graze.and keep the people safe & clean . by putting the trash in the proper place.Mother Earth will feel better about us and will allow us to live here, longer safe and secure. like we pray for.

Fig. 3.19 The Land is Precious



Before & After Before - the land is in poor shape, the water is held back with dams. the crops can't be raised. the animals over graze, and could be feed from growing our own hay ect. The trash is thrown out by everyone who have lost heart for the area. the open pits are burnt and polluting the air we pray for.the cars themselves are polluting as well. After - the land is cared for - generation after generation.a place where the young ones want to return to. The land is green with clear blue water flowing to the crops.where happy hearted people can grow healthy produce & sell in Co-Op's for economic development. places where people can learn about new ways to build & new types of energy sources. like wind generators & solar.and share this with the communities around us!

Fig. 3.20 Before & After



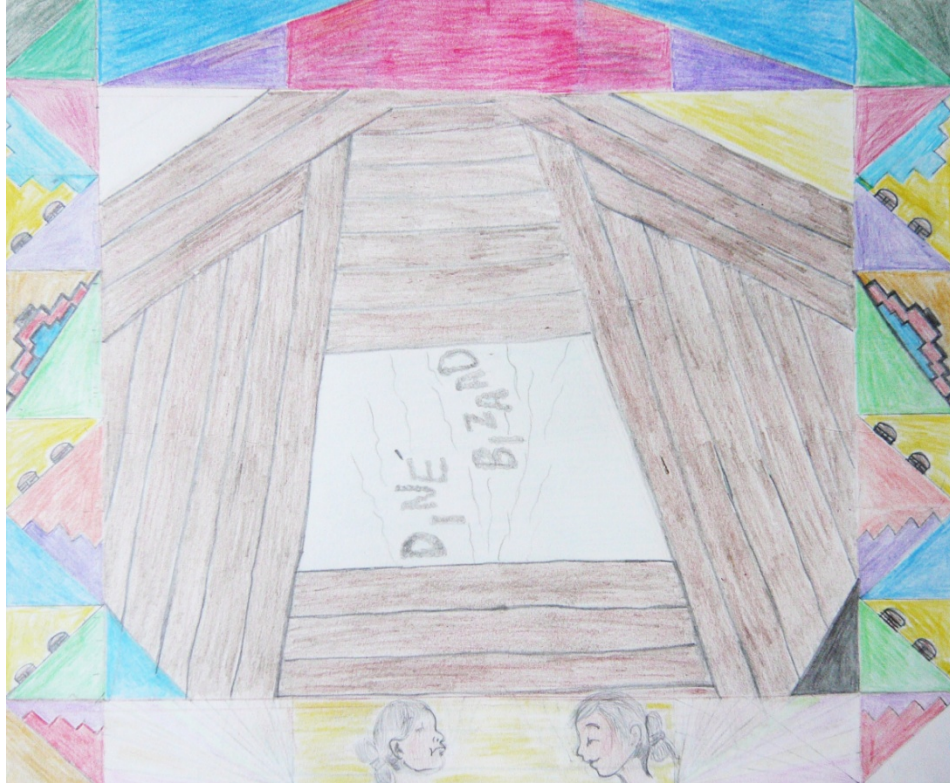
“We are still waiting for the new water line. If we get the water line, it will serve many communities, like Burntwater. Some of us don’t have showers, or bath rooms. Some people lives in trailer with water heater, shower and everything, but they don’t use it because of no water. As long as I remember, me and one of my cousins we use to haul water from quite a distance. My grandfather on my father side use to haul water in a wagon w/2 barrels. Today, we still haul water.”

Fig. 3.21 Running Water



“In this picture I’m thinking people need to understand what recycling means. to me it means popcans, plastic bottles, Glass bottles people discovered in these items I explained are all recycled and are made into thing that are put to use after you Recycle them you reuse them like that movie called “Tornado” the popcans in that movie is used to prevent “Tornados” and now you have to Reduce the pile of things that people call trash now these days.”

Fig. 3.22 What Does Recycle Mean to Me?



“When I was a little girl, I remember I was put in school at Mariano Lake Boarding School at the age of 8. I didn’t learn my second language until at the age of 10. It was really hard. When the white teacher was trying to teach us some words and I never knew what she was saying. I felt like running away and I was really homesick too. Somehow I survive and I was already in the 5th grade. I think I repeated 4th grade twice. Today, the SES students K-5 don’t know how to talk in their native language. It really hurts me and I teach them some Navajo words. The parents is the answer, they are the ones should teach them. In my drawing, I thought about the hogan, because that where all the teaching starts and today the younger generation are the ones that should be taught the Navajo Language on everyday basis.”

Fig. 3.23 Diné Language Is Going



“Ever since my childhood, we had no electricity whatsoever. I was raised in a remote area on NE of Hosta Butte in Mariano Lake, New Mexico. I still remember, that we use to use kerosene lamp. We had two of them in a one room log house. In fact, up to this day, where I was raised, my mother and two sibling still don’t have electricity. The house has been rebuilt and its been wired and my mother is still waiting for the lights to come on, at 9 1 yrs old she’s still waiting. In 1975, I got married, in the same location where I was raised, still no electricity. Me and my husband we moved to Burntwater, Az Oct. of 1975 and from there we attended Chapter meetings and we got help with the Powerline Extension, the lines finally reached our home in 1978. By that time I had 3 kids and another one on the way. Its really hard, when you don’t have electricity, but in a way too, I always think that w/out lights, as a young girl me and my sisters we use to go out and do some house chores; like hauling woods w/wheel barrel, do sewing, help out with crops, do some art work, walking, exploring mother nature and help our mother with weaving. And thats the way it was w/out TV On the reservation, we still have thousands of households that don’t have elec. And to one, as of this day we need it for our children, grandchildren and for health wise.”

Fig. 3.24 Electricity on Navajo Nation



I drew these pictures for a reason because everybody's doing this to mother earth I never seen when I was little I see a lot of trash on the roads where I live. A lot of garbage, and a lot of people dump, dump a lot of trash on the road and they're just doing this to mother earth on, where how we live, where we, where we live in this reservation. This is, we live in, this great land of ours and mother earth. I drew this picture because, I imagine that some people always drive, drive fast on the road, dump a lot of stuff, dump washer ma, washer machines, ovens, and unmade tires and beer bottles. These people are really not doing so good on mother earth. Mother earth give us oxygen how we live on this earth ...

Fig. 3.25 Factory Polluting Lake



“I was wonderin it can be rebuilt again and put a reserve, or how do ya call it, for fishin or boatin, cause there’s usually a lot of water in that canyon. And I just drew a ah picture how it should look like. And we need to build a bigger higher dam so water wont go over again, so that’s what I was thinking of so it would have been really good to benefit the people that are livin lower in the valley to start their irrigation again and so they can plant watermelon, corn, squash or alfalfa. Alfalfa was mostly everybody used to grow in the valley. And there’s irrigation ditches still there and they just need to be cleaned up so this is what I have from one of my elderly person. I guess that was when they were young people. That’s how they started. “

Fig. 3.26 Houck Dam

Learnings

In addition to identifying a common community concern to be addressed, this dual method served a vital purpose in initiating the beginnings of collaboration around a focused engagement to draw in participants, to allow for individual expressions of community issues through these media and for oral expressions in community gatherings in the form of stories and narratives. In the process of doing this, learnings occurred and adaptations were made not only by the participants but by me as the researcher as well, i.e., we were all engaged in building capacity and adapting—a process of *collaborative adaptive capacity building*.

I found the process of deploying these methods in the rural area of Houck to be very challenging and difficult logistically at first and as time went on the process began to take shape. One of the very first community gatherings that were held at the Houck Chapter House was broadcast to the community through flyers posted in strategic locations, by word of mouth networking and even radio spots. Yet despite all of my best efforts with the assistance of some of the NABI staff, we experienced a much lower turnout than I expected, particularly when free cameras and art kits were being given away and door prizes were being raffled off. The learning I took from this was to be extremely patient in the ways of the Navajo. The meeting was set for 1:00 PM and eventually by around 3:00 PM a handful of people had arrived to hear about this new “gig” in town. Another learning and adaptation made early on was that the location of the Chapter House was not the best location and that I needed to lower my expectations to a smaller more localized area. That is when the decision was made to no longer focus on the greater Houck community but to narrow down to primarily the Burntwater vicinity

and to concentrate the activity and gatherings at NABI using their facilities. From that initial launch, small and insignificant as it was, the process gradually warmed up and built momentum over time during monthly trips out in the autumn and winter of 2010. At the end of December, despite a severe snow storm making the roads difficult to traverse, Phase-I concluded with a successful well attended community gathering of photo and art sharing, storytelling, feasting, a gift exchange and a raffle for first, second and third place awards.

In hindsight and after reflection with my committee members as a type of triangulation/peer review, it is quite possible that the type of medium, be it photovoice or artvoice, could have had an impact on the outcome that is worth noting here for future researchers. For example, a participant might have found it relatively easy to convey an abstract idea such as electricity or language through art given the wide latitude that art offers in terms of creative thinking. However, such themes may not be so easily captured through photography. On the other hand, cameras were easy to take around and use quickly without having to set up as one does with an art kit. Of the data I received back all photos were of tangible objects such as buildings, landscapes, objects, trash sites, etc. While the art samples included such tangible objects, they also included abstract concepts such as language, electricity and the need for flowing water in a house. It is not to say that such abstract subjects could not somehow have been captured through photovoice or at least some vague notion of the idea and then explained through the narrative piece but in this exercise they were not. Perhaps had those participants who focused on such abstract ideas been given cameras they would have still focused on these topics. This leaves open a realm for further investigation by perhaps a Diné College student.

The successful conclusion of Phase-I, where a community theme had been born and adopted with full support and collaboration, enabled a natural and seamless launch into Phase-II. It was in Phase-II that the participants gathered on a regular basis to explore specifics behind the issue of illegal trash dumping through an application of the iterative *collaborative adaptive capacity building* process model within the context of the PSFA-CACB model.

PHASE - II: COLLABORATIVE COMMUNITY GATHERINGS

MODEL 1: *Participatory Social Framework of Action - Collaborative Adaptive Capacity Building* (PSFA–CACB)

As first introduced in Chapter 1, the *Participatory Social Framework of Action – Collaborative Adaptive Capacity Building* (PSFA-CACB) model (Fig. 3.27) conceptually depicts the dynamics of collaborative human interaction with an objective of decision making and in this context, decisions regarding the environment that are oriented towards a more sustainable outcome.

The dynamics of the CACB component to this model can be seen as a reflexive integrative process shifting in complexity as adjustments are made from feedback loops derived from learning in action, reflection, consultation and accompaniment as depicted in Fig. 3.28. In the context of this study, the notion of consultation and collaboration go hand-in-hand (see Chapter 2). In practice, the collaborative consultations that occurred during this study have been enriched with elevated demeanor, patience and insights of the Navajo, which I have not typically seen in other western settings. This was experienced during the informal Thursday collaborative gatherings and conversations integrated with

a local community initiative revolving around a Prayer Hogan gathering and a community dinner sponsored by The Native American Baha'i Institute (NABI, 2012) that has been in the area for many decades. These consultation gatherings have been all inclusive with an open door policy encouraging involvement, action and accompaniment

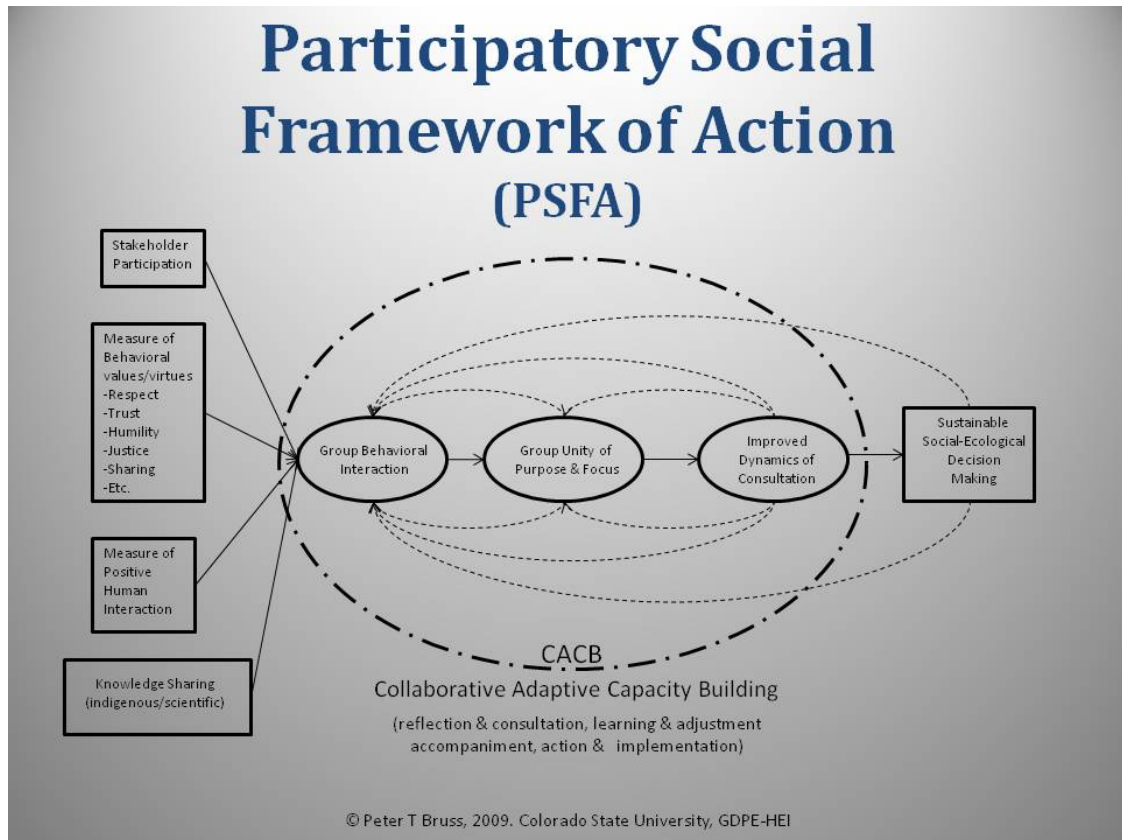


Fig. 3.27 PSFA-CACB Model

in the exploration/research process. Further underlying the success of the collaborative-consultation outcomes in the NABI environment is the way in which individuals have interacted with each other showing a great degree of patience, humility, and respect. As Phase-II evolved there was direct evidence of sustainable progress through noticeable continual engagement due to weekly Thursday meetings organized by the volunteer participants themselves followed by a community dinner offered through NABI. This

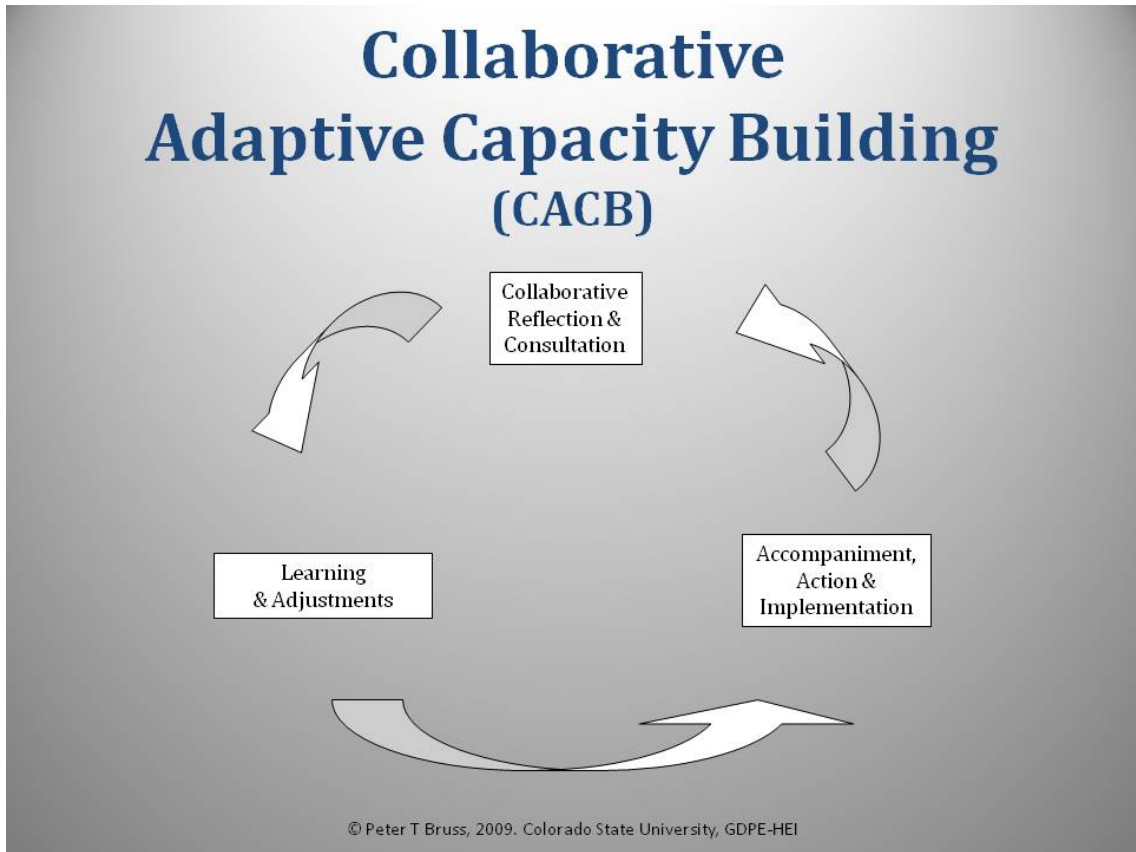


Fig. 3.28 Collaborative Adaptive Capacity Building (CACB)

continual engagement process supported by a local institution has been a vital component in capacity building not only in my study but as experienced elsewhere. For example, a collaborative study by Fazey et al. (2010) showed that working with local institutions and organizations enhanced collaboration and the overall learning experience that contributed to local community capacity building and self-directed and place-based problem solving. Reid et al. (2009) through applications of a continual engagement model showed how progress achieved by the protracted project could build capacity at the individual and institutional levels by engaging participants and integrative processes at multiple levels; noting that the researchers themselves built capacity as well during the process, as was

the case in this study. Further to the Reid et al. (2009) example there are already opportunities for boundary spanning resulting from my study as the participants reach out to local civic and business interests and accompany as co-presenters in conference presentations. This will no doubt continue as opportunities arise to share final research results at the Chapter, Agency and Navajo Nation community levels.

Results and Learnings

Phase-I and Phase-II were designed to create individual awareness that could lead to collective change. This is essentially the focus of the first of three research questions set up at the beginning of this chapter. However, it is Research Question 1 that specifically pertains to Phases I & II.

Q1 – How can a participatory research process using photovoice, artvoice and applications of the *Participatory Social Framework of Action - Collaborative Adaptive Capacity Building* (PSFA-CACB) conceptual model create individual awareness to bring about collective change and sustainable action to improve the environment and address local energy needs?

The photovoice and artvoice methods used in Phase-I were very effective in rallying the participants around a focused task and objective. The success of this Phase was seen in not only the exuberance and keen interest shown by not just the participants but also many others in the community who attended. This was particularly remarkable given the very difficult weather conditions. Another indication of success was from the continued request by residents in the area asking for more cameras or art kits as they were interested in participating. To this end, I was unable to distribute more than what the budget allowed. However, creative ways of sharing among friends and within families to

take pictures or create art is perhaps another measure of success of the program. This process was instrumental in bringing about a collective awareness of the community-wide problem of illegal trash dumping (see Appendix 3.3 for more pictures of illegal trash dumping in the Houck area). During the several months of taking pictures and creating art there was an apparent energy in the discourse on this matter, particularly noticeable in the Thursday evening Prayer Hogan sharing and conversations during dinner when periodic updates would be given by me during my visits. This energy and collective awareness began to be refined and focused during Phase-II when weekly meetings were held to begin exploring the issues behind this problem and to begin discussing potential solutions. At the outset, the group began to explore the conceptual idea behind the CACB model and how it related to the phased approach being taken. This really helped many participants to begin to see the bigger picture of where this project was going. Volunteers arose to take on various tasks including one who skillfully drew the path of the successive phases of collaborative capacity building the project is following (Fig. 3.29). Each phase takes on its own form and character such as in my research Phase-I involved artvoice and photovoice, Phase-II takes on more of a community gathering and consultation form and Phase-III is about taking the results from the previous phases and working them into a model for sharing. Yet a central theme that has been discussed and in many instances applied as part of the collaborative learning and capacity building process is the iterative cycles of consultation and reflection, learning and adjustment and action and accompaniment. Throughout the weekly meetings new

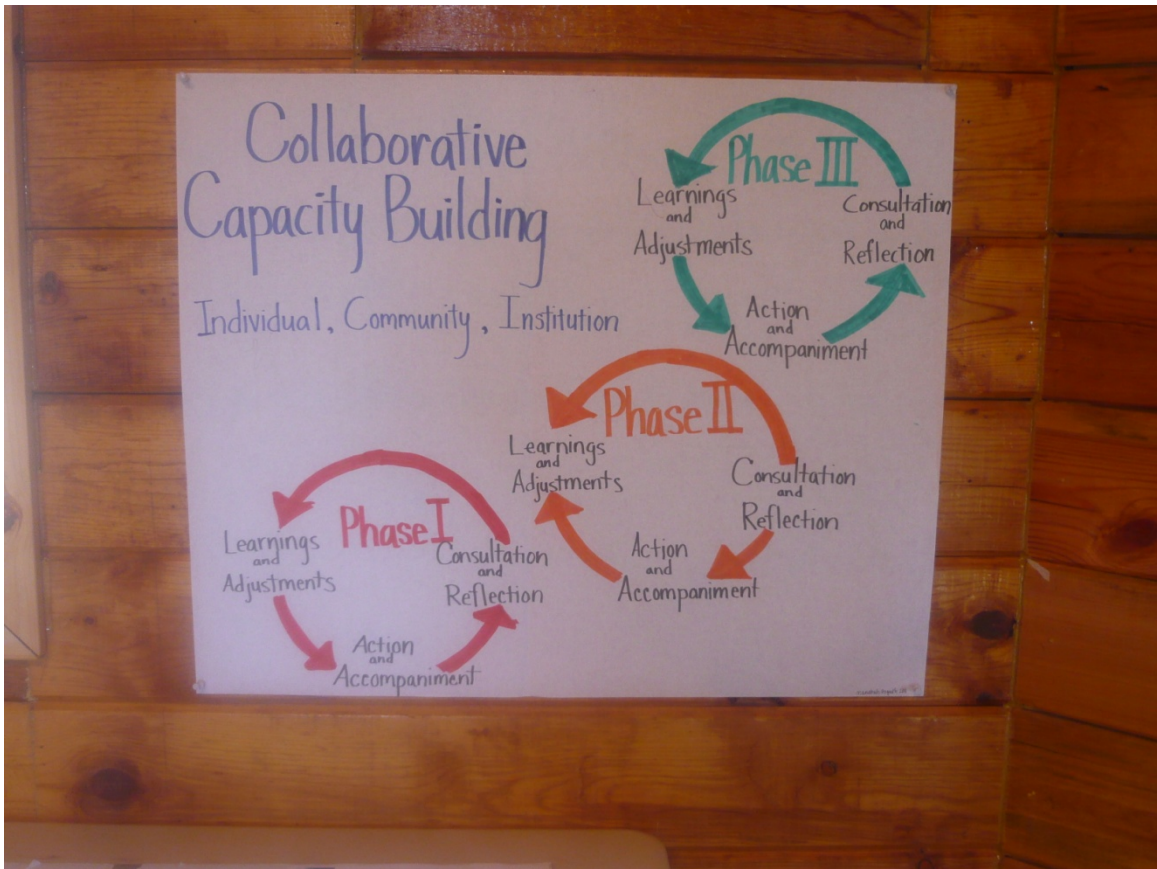


Fig. 3.29 Tri-Phase Path to Collaborative Adaptive Capacity Building

developments would emerge as we worked through the project problem. One of the first tasks was to identify the nature of the illegal trash-dumping problem and map out what it was that people were dumping as well as some of the underlying issues behind this behavior. This was done in a reflective and consultative atmosphere resulting in an evolving “Issues/Problem Map” (Fig. 3.30). In no particular order, some of the underlying issues identified included:

- Disrespect for mother earth
- No money for trash bags
- No designated place to dump trash
- Poverty
- No communication
- Human behavior linked to laziness, not caring and selfishness

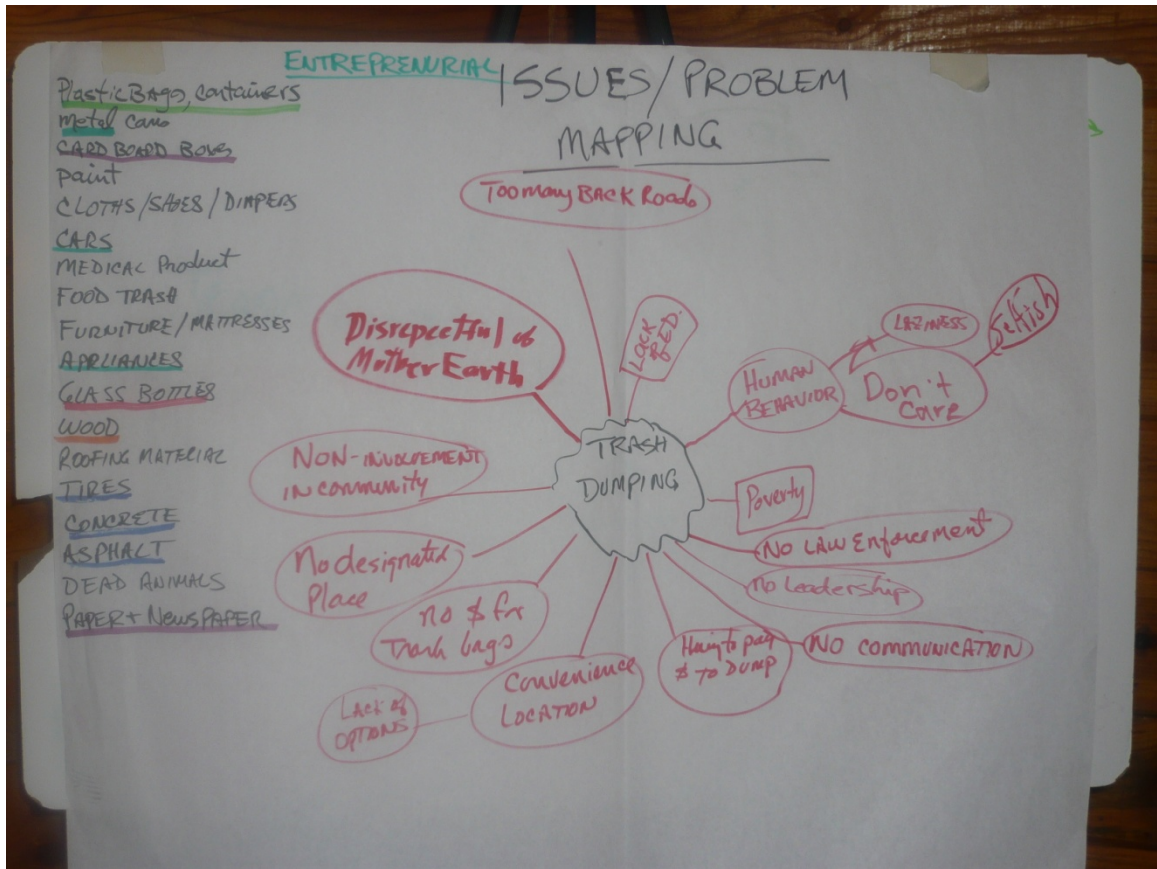


Fig. 3.30 Issues/Problem Map

At one of the meetings, a participant showed up with “a cleaned up version” of the map (Fig. 3.31) as he said he liked neatness and balance and did not like to look at a messy map with no straight lines. This was a typical example of engagement, taking ownership and leadership—all distinct measures of project sustainability. Another question we asked in one of the weekly gatherings was where all this trash located and that then became another goal and cause for action. The participants were asked to go out and during their daily activities to take note of where they see illegal trash sites. This information was brought back into a reflection gathering and we consulted on this. One of the participants had a satellite image of the area and we used that to begin pin-pointing illegal trash sites (Fig. 3.32) that then also became a subject of discourse during the



Fig. 3.31 Issues Mapping Cleaned Up

Thursday night community dinners. The mapping idea then extended into the creation of a board game called *The Houck Community Environment Game* (Fig. 3.33 thru Fig. 3.377 and Appendix 3.4). The participants enjoyed playing this as part of an exploratory exercise that brought about even greater awareness to the issue of illegal trash dumping from a different creative and fun perspective. One of the features of the game was that as players occupied a common space on the board they were asked to draw a card with a question about the environment and illegal trash dumping pertinent to the local surroundings. They were then to engage in a dialogue around this question—a feature that ended up in the simulation model built in Phase-III as discussed below. At another weekly meeting we undertook an exercise to improve on the game with an evaluation of



Fig. 3.32 Mapping of Illegal Trash Sites

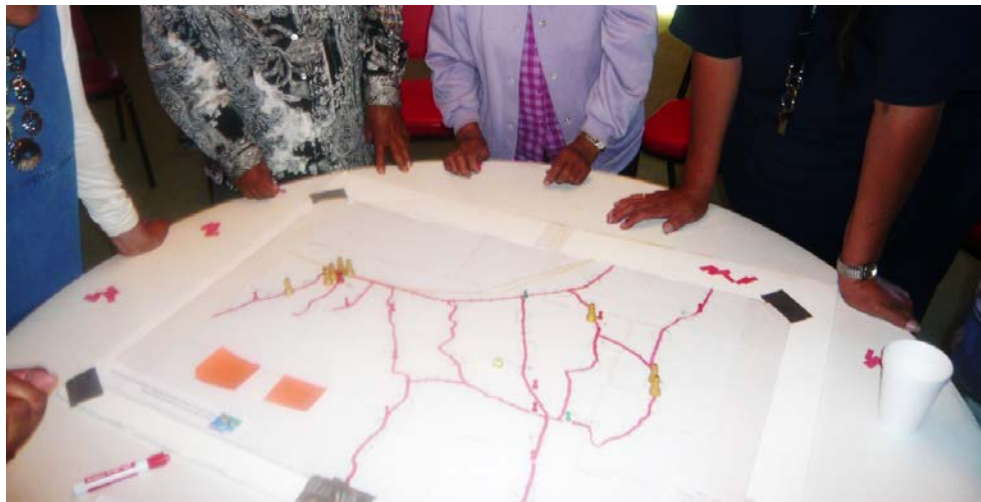
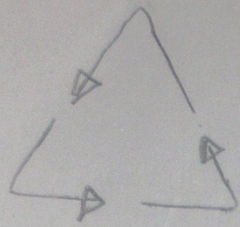
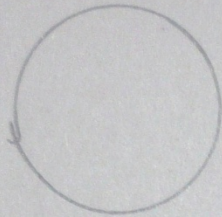


Fig. 3.33 Playing the Houck Community Environment Game



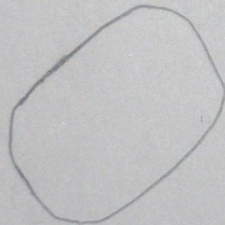
Recycle Zone

- go to nearest trash site + collect trash



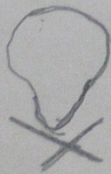
Collaborative Consultation GATHERING ZONE

- Accompany nearest opposite player to Nearest CCG
- Reflect on a question from stack
- Proceed to Legal Trash Dump
Trade in Trash for COOP-credits



CAUGHT DUMPING ZONE

- Go to Chap House for time out - MISS one Turn



POLLUTION ZONE

- Go to Chap House Infirmary For Healing MISS one turn.

Fig. 3.35 Game Actions

THE GAME FEEDBACK

How many Liked it? $8/8$

How many did not like it? why

How Can we IMPROVE IT?

- How to ask deeper/serious Q?

1. - if we continue to dump at current rate where will we be in 5 yrs.?

2. How do we educate community to change dumping behavior

3. Do people realize the health problems dumping creates?

4. How can we make trash collecting safer?

Fig. 3.36 Game Questions

5. Are you afraid to pick up trash? why?
6. Do you ^{think its OK to} dump trash on our mother earth?
7. If you have a trash bin near home do you think you would use it instead of dumping trash on Mother Earth?
8. ~~Do you think~~ ^{How can we get} the Chapter leadership to ~~should~~ get involved?
9. ^{How} Would it help to use the network for Community Service to promote trash clean up
10. If you think this is a good idea how would you volunteer your service
11. Do you think its a good idea to have extra dumpsters in Hawk Chp.
12. What is a reasonable price ~~for~~ fee \$ to dump trash? Per/bag

Fig. 3.37 Game Questions cont.

how we could modify the type and depth of questions that are to elicit dialogue. Here are some results from this activity.

Phase-II quickly began to take on a shape and form by itself as the participants became more and more engaged in the weekly gatherings. This gave rise to an emergent leader who engaged the community to rally around this opportunity. Letters of invitation were sent out to local officials, organizations, businesses and churches as well as to leaders of interest at the Navajo Nation level such as the EPA and Municipal Solid Waste Department inviting them to attend a local community exploration and discourse on the illegal trash dumping problem in the Houck Chapter and to discuss possible solutions. Several of these meetings took place over the course of several months culminating in a community wide trash clean-up during the summer that resulted in a lot of Navajo Nation publicity on the radio and in the newspaper (Appendix 3.5) The person who took charge was awarded a Navajo Nation EPA award for community involvement.

The combination of Phase-I and Phase-II was a success in so many ways as participants witnessed the birth and growth of a process in their own community and how it took on a shape of its own to result in real grass roots action. As Phase-II started to wind down in the Fall of 2011 an opportunity arose for me to attend a conference on social and economic development. In the spirit of accompaniment within the *collaborative adaptive capacity building* process I wanted to share this opportunity with a couple of the Navaho participants. Through NABI coordination and assistance it was made possible for two Navajo to accompany me and fly out to Orlando, FL where they participated in the conference proceedings and shared of their experiences in working on this project. They also gained a lot of insight from other international social and

economic development initiatives that were being presented at the time. One of the participants had this to say about her experience in a thank you letter to me:

Thank you so much...for making my trip to Florida possible, I mean this from the bottom of my heart!

This trip gave me the spiritual energy to move forward with our continued capacity building project here in Burntwater. I came home so inspired it was as if I was sitting on top of the Delta Airplane coming home!...

With that in mind, we have started our weekly Thursday meetings again by posting fliers, and informing the community members at our Thursday dinners. I have invited Apache County Attorney, Mr. [left blank], and Mr. [left blank] of the Navajo Nation Waste Management to our meetings on January 26, 2012...I will go to the Navajo Nation Broadcast Service, they disseminate announcements to all radio stations serving the Navajo Nation on AM/FM stations, to announce our upcoming meetings. I will also drive house to house to notify people handing out fliers. NABI will continue to record our sessions...

That brought Phase-II to a conclusion. With the knowledge and information learned from the field exploration of both Phase-I and Phase-II it then became possible to create two agent-based simulation models to further explore and examine this issue of illegal trash dumping and what possible entrepreneurial solution might arise. This was done in Phase-III.

PHASE – III: AGENT-BASED MODELING

Phase-III was all about applying the knowledge and information learned during the field exploration, Phase-I and Phase-II, to develop an agent-based model (Chapter 4). The model, *Taking Care of the Land – Human Environment Interactions* (TCL-HEI) is comprised of two parts. Tier-I is the first or base component and represents a stylized depiction of human behavior concerning illegal trash dumping in the Burntwater vicinity

of the Houck Chapter. It involves the consultative interaction of people who have one of three types of value orientations towards the environment: *uncooperative*, *cooperative* and *environmental steward*. Tier-II is the second component and revolves around a conceptual model *Regional Cooperative Clean-Energy Economy* (RCCEE – see Chap. 4) that theoretically depicts processing solid waste into clean-energy (ethanol) using a clean-tech waste-to-fuels process.

During the development of the TCL-HEI model, feedback from some of the exploratory research participants was sought. This was helpful in grounding some of the aspects of the model that would have otherwise remained too unrealistic. By design, models are meant to be kept as simple as possible and not be a true replication of reality. However, getting feedback from a local perspective is a good way to seek validation as discussed above. Seeking feedback also served as another way of fostering collaboration and including the participants in aspects of Phase-III so they could learn and see how their involvement in Phases I and II significantly contributed to the development of the TCL-HEI model. Chapter 4 is devoted entirely to looking at these models and the discovery process and results from simulation runs.

DISCUSSION: A TRI-PHASE APPROACH TO *COLLABORATIVE ADAPTIVE CAPACITY BUILDING*

Using a tri-phase approach to this research was logistically perhaps the best way to proceed as it split the fieldwork into three distinct and manageable phases that were easily identifiable by the participants (Fig. 3.38). Phase-I was essentially the opportunity to get the process moving and off the ground and it took nearly that entire phase of six

months, including the early visits to the Chapter House when I was seeking a Chapter Resolution, to begin the research process in Houck. Even those early days were both

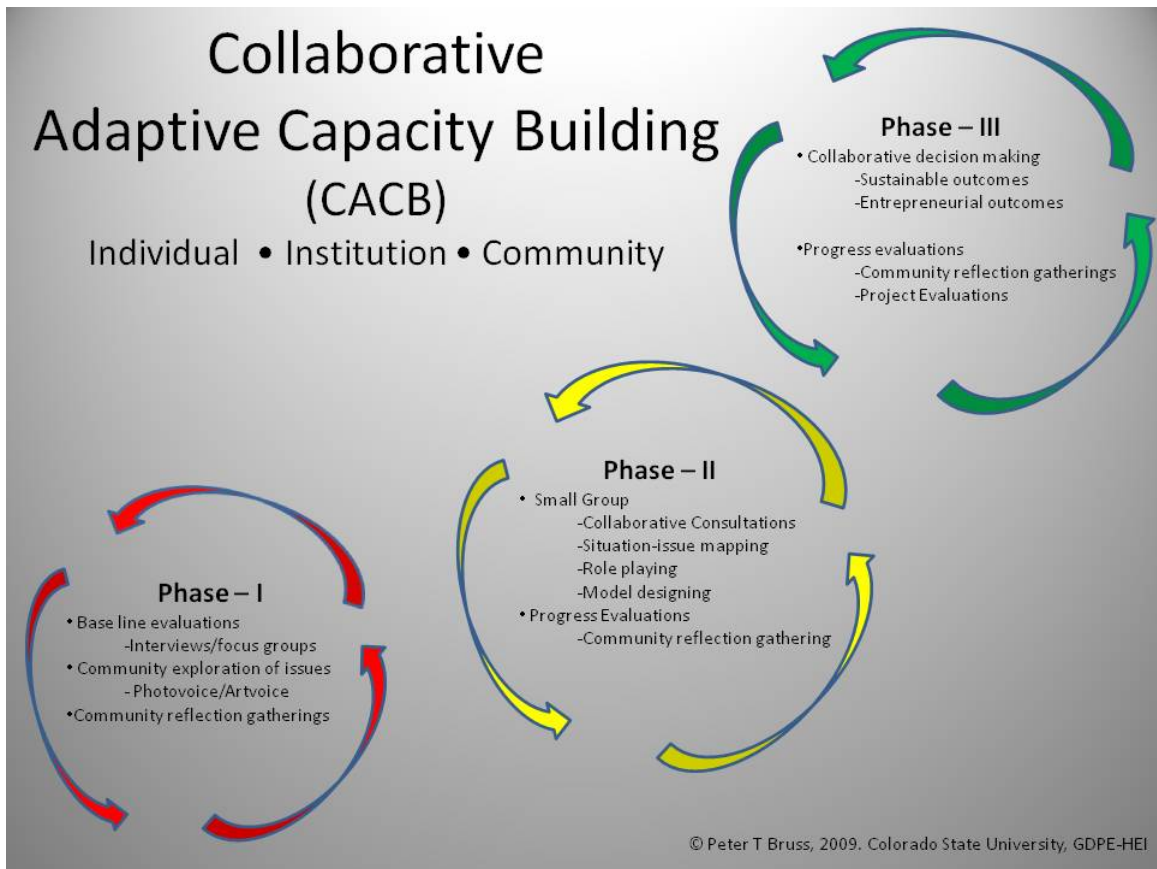


Fig. 3.38 Tri-Phase Application of CACB

informative and collaborative as I worked with several of the local residents to get acquainted and become familiar with my new surroundings. However, after six months towards the end of Phase-I in December, the process was well underway and ready for a hand-off to Phase-II that lasted for nearly nine months into the Fall of 2011. Applying the CACB model in their own way through routine weekly meetings to reflect and consult on actions and learnings, the climax for Phase-II was the self-organized participatory trash clean-up that occurred over the summer. Phase-III began as an overlap with Phase-II as I

began working on developing the models early on in order to tie in some of the data and feedback from the field site with the model development. Then Phase-III went through a solitary period where I was working alone on the models to get them refined and operational. Towards the end of Phase-III, I was able to re-emerge in the field and on several occasions share the models with some of the participants. I was able to get their feedback and insights as to not just their overall impression of the models as a representation of their reality in the context of the project they had been working on for over a year but also some deeper insights into the workings of the models. Further, the Tier-II component revolving around the *Regional Cooperative Clean-Energy Economy* conceptual model was something they had not yet related to as it portrays a possible theoretical entrepreneurial solution to a very real problem they had been working on at the local level. I believe this was a moment of further vision making, hope and collaboration for many of the participants. To know that it doesn't have to end at Phase-III but in fact with assistance from policy makers and officials at the local and National levels on the Navajo Nation there in fact could be more to this novel and more holistic research approach to problem solving a complex social-ecological system in the Houck Chapter. The models have the capability of influencing policy makers, training practitioners and educating the public all of which is a facet of *collaborative adaptive capacity building*.

This overall approach and method has shown signs of adding value to the local community through its hands on practicality, ability to build skill, confidence and learning and overall capacity building. There have even been visible signs that the process is moving in a sustainable direction through self-directed local leadership and

drive. The individual and collective capacity of the participants has been raised to identify and resolve issues through this collaborative social research tri-phase / dual-model method. A discussion and synthesis on how this translates more fully into a resilience framework is presented in Chapter 5 after an analysis of the agent-based model *Taking Care of the Land – Human Environment Interactions* (TCL-HEI) in Chapter 4.

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APPENDICES

Appendix 3.1 Places in the Houck Chapter



Fig. 3.39 Town of Houck and surroundings



Fig. 3.40 Houck Chapter



Fig. 3.41 Houck Chapter House



Fig. 3.42 Historic Burntwater Well-House



Fig. 3.43 My Jeep at the Querino Trading Post



Fig. 3.44 Entrance to NABI



Fig. 3.45 The Prayer Hogan



Fig. 3.46 The Prayer Hogan Interior



Fig. 3.47 The Big Hogan

Appendix 3.2 Background on the Baha'i Faith

Information here is excerpted from the website Bahai.org (Baha'i, 2012).

Founded a century and a half ago, the Bahá'í Faith is today among the fastest-growing of the world's religions... with more than five million followers, who reside in virtually every nation on earth... [residing] in more than 100,000 localities around the world, an expansion that reflects their dedication to the ideal of world citizenship. The Bahá'í Faith's global scope is mirrored in the composition of its membership. Representing a cross section of humanity, Bahá'ís come from virtually every nation, ethnic group, culture, profession, and social or economic class. More than 2,100 different ethnic and tribal groups are represented. Since it also forms a single community, free of schism or factions, the Bahá'í Faith comprises what is very likely the most diverse and widespread organized body of people on earth. The Faith's Founder was Bahá'u'lláh, a Persian nobleman from Tehran who, in the mid-nineteenth century, left a life of princely comfort and security and, in the face of intense persecution and deprivation, brought to humanity a stirring new message of peace and unity. Bahá'u'lláh claimed to be nothing less than a new and independent Messenger from God. His life, work, and influence parallel that of Abraham, Krishna, Moses, Zoroaster, Buddha, Christ, and Muhammad. Bahá'ís view Bahá'u'lláh as the most recent in this succession of divine Messengers. The essential message of Bahá'u'lláh is that of unity. He taught that there is only one God, that there is only one human race, and that all the world's religions represent stages in the revelation of God's will and purpose for humanity. In this day, Bahá'u'lláh said, humanity has collectively come of age. As foretold in all of the world's scriptures, the time has arrived for the uniting of all peoples into a peaceful and integrated global society. "The earth is but one country and mankind its citizens," He wrote. ...It takes a distinctive approach to contemporary social problems...from new thinking about cultural diversity and environmental conservation to the decentralization of decision making; from a renewed commitment to family life and moral values to the call for social and economic justice in a world that is rapidly becoming a global neighborhood. ...For a global society to flourish, Bahá'u'lláh said, it must be based on certain fundamental principles. They include the elimination of all forms of prejudice; full equality between the sexes; recognition of the essential oneness of the world's great religions; the elimination of extremes of poverty and wealth; universal education; the harmony of science and religion; a sustainable balance between nature and technology; and the establishment of a world federal system, based on collective security and the oneness of humanity...

Appendix 3.3 Photos: Illegal Trash Dumping - Houck Area









A community participatory exploration of the environment, renewable energy, human capacity building and entrepreneurial solutions

THE HOUCK COMMUNITY ENVIRONMENT GAME

Objective: Moving along the red road system and following the actions of each zone landed on, your overall objective is to clean up as many of the illegal dump sites (red pins) as possible and to exchange your trash (red chips) for energy coop-credits (green chips). At the end, the player with the most coop-credits wins, but really everybody wins because your environment is now much cleaner and your children safer and healthier.

- You must enjoy, have fun and learn about your community's environment.
-
- There are many ways this can be played, use your imagination. Feel free to change the rules but do so in group unity and consultation so all are happy.

Here is one way to play:

- 1. Each player chooses a board piece. Remember your number, and place your piece anywhere on the red road system of the Houck Chapter area.**
- 2. Choose among you who will be the "Environmental Banker". The EB hands out 5 red trash chips to each player. Everyone produces trash and this is your trash to begin with.**
- 3. The board is set up with:**

- a. red pins - illegal trash dumping sites
 - b. green pins – Centers for collaborative consultation gatherings
 - c. Zones that trigger certain actions when landed upon (see board key for action detail).
4. Each player takes a turn rolling the dice and moves their piece in accordance to the number on the dice. Use strategy to choose the best possible move to better your chances at winning.

Exploration Questions

- If we continue to dump at our current rate where will we be in 5 years?
- How do we educate the community to change dumping behavior?
- Do people realize the health problems that dumping creates?
- How can we make trash collecting safer?
- Are you afraid to pick up trash? Why?
- Do you think it's OK to dump trash on our mother earth?
- If you have a trash bin near your home do you think you would use it instead of dumping trash on mother earth?
- How can we get the chapter leadership to get involved?
- How would it help to use the radio for community service announcements to promote trash cleanup?
- If you think this is a good idea how would you volunteer your services?
- Do you think it's a good idea to have extra dumpsters in the Houck Chapter?
- What is a reasonable price or \$fee to dump trash (\$/bag)?
- Why do people dump trash along the roads?
- Do you think people dump trash in secret or in open view?
- How often do you think people dump trash along the roads?
- Where does dumping take place?:

- a. Close to home**
- b. Far from home**
- c. Site where trash already exists**
- d. New site**
- e. Any where**

Appendix 3.5 Phase-II Community Action Press Coverage

THOREAU brawl gets worse when police arrive

By Michael Sullivan
Staff writer

THOREAU — A brawl in Thoreau Wednesday didn't end when McKinley County Sheriff's deputies and Navajo Nation Police arrived to break it up; the combatants simply turned their anger upon law enforcement.

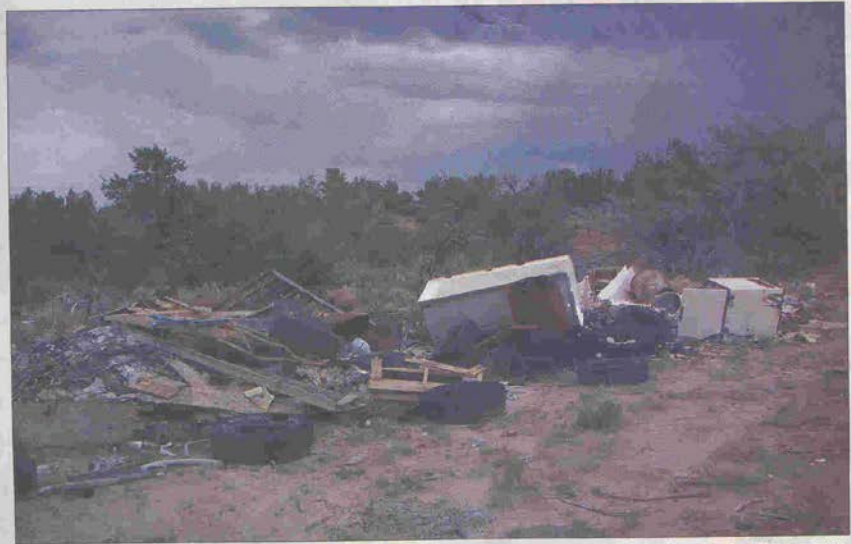
Deputies Ben Benally and Elreno Henio were dispatched to 306 County Road 27 shortly after 5 p.m. to investigate a report of several people fighting with bats and bars. They spotted one man who appeared to have been involved, while others dispersed in different directions.

Dan Yazzie's clothing was torn, indicating he had participated in the fray. When the deputies started to restrain him, he resisted and had to be taken to the ground and handcuffed. Henio said he smelled of alcohol. Another man was nearby, shirtless and carrying a long kitchen knife "in an aggressive manner," the deputies reported. As the deputies approached him with their weapons drawn, he went inside a mobile home. Deputies learned that children were in the residence at the time. Benally and Deputy James Maiorano were able to get some of the children out through a bedroom window, while Henio held the knife and exiting the residence through a window.

Navajo Police Officer Jones after a struggle. Thompson Morgan was taken into custody after dust had settled and took by hogan in a highly irate. Calls to the NPD jail information were unanswered.

Mon. July 18, 2011

Walk in beauty?



Babette Herrmann/For the Independent
One of three illegal dump sites within a half-mile radius in Burntwater, Ariz., is seen Sunday



Brian Leddy/Independent

Jon Francisco piles garbage up on the side of the road during a trash cleanup near Burntwater Tuesday. The communities of Houck, Burntwater and Pine Springs participated in the cleanup.

Trash pickup

Wed. July 20, 2011

Continued from Page 1

is by participating in all phases of a project, such as the trash pickup effort.

"I like projects that help the community from the inside out," he said. "To me, it's more meaningful."

Up the road from Foguth, the charismatic and outspoken Houck, Ariz., resident Jon L. Francisco, who donned a blue jumpsuit to protect his clothing, plucked trash out of the most prickly of shrubs while speaking candidly about the excess of beer cans and booze bottles that litter the roadside.

"Tourists come from far away. ... There are beer cans along the road," he said. "It makes us look like we're a bunch of drunks that are living here."

He said the trash in the area takes away from the raw beauty of the surrounding trees and conflicts with Navajo culture and beliefs.

"Those cedar trees are there for a good purpose, they are our medicine," he said. "People don't respect that."

Francisco said he would like to see the cleanup effort take

place during the summer, spring and fall. And he's not alone. Morgan said the cleanup committee meets every Thursday at NABI and she plans on discussing with members on whether to schedule another trash pickup event on a Saturday and sometime in the fall before Thanksgiving.

As for her thoughts on what disappointed her that day, she felt let down by the local businesses in the area that failed to step up to the plate by providing labor or donating supplies.

"They can't just take and take," she said. "They need to give back."

She credited Bruce Burnham of R.B. Burnham & Co. Trading Post in the reservation border town of Sanders for providing supplies for the cleanup.

The next phase of the cleanup initiative entails addressing the massive cleanup of dumpsites in NABI's neck of the woods. It's something that local Houck resident Marge Brown can appreciate. She moved quickly as she picked up trash off the ground, near her home, on the frontage road that runs parallel to Inter-

state Highway 40.

Brown stopped for a moment to share that she was happy to contribute to her community, but also shared that she struggles to keep illegal dumping out of her backyard.

Just up the hill from her house is a makeshift dump. She has tried to discourage dumpers by blocking the road with tree branches and bushes, but to her frustration, those determined to litter find their way in.

"I wish (the chapter) could have a local trash dump," she said, adding that illegal dumping boils down to some "people that don't want to pay" to dispose of their trash.

The Houck Chapter House charges a small fee to residents that choose to dispose of their trash in the large dumpster. There was no charge for bags of trash dropped off on behalf of the community cleanup.

Meanwhile, Morgan credited the media for attracting two volunteers from Fort Defiance, Ariz., that make a living picking up scrap metal items, including stoves and refrigerators, which are often seen at illegal dump sites on the reser-

vation. They hauled away a few of these items on their flatbed trailer that day and are coming back for more, she said.

Jerry Bathke, co-administrator of NABI, said the real underlying advantage to hosting the cleanup is raising awareness across the Navajo Nation.

"On one hand it's an event," he said. "On the other hand it's an educational tool."

And the viewpoint of Thomas Bitsoi, an environmental specialist for the Navajo Nation Environmental Protection Agency, parallels Bathke's. He explained that part of his job entails going to chapter houses to speak on topics of environmental concern, such as littering, but few do anything at all to curtail the problem.

Bitsoi lauded the community for setting precedence in the sovereign nation. "I think they're a good example as far as trying to make a difference, not just for here, but the Navajo Nation."

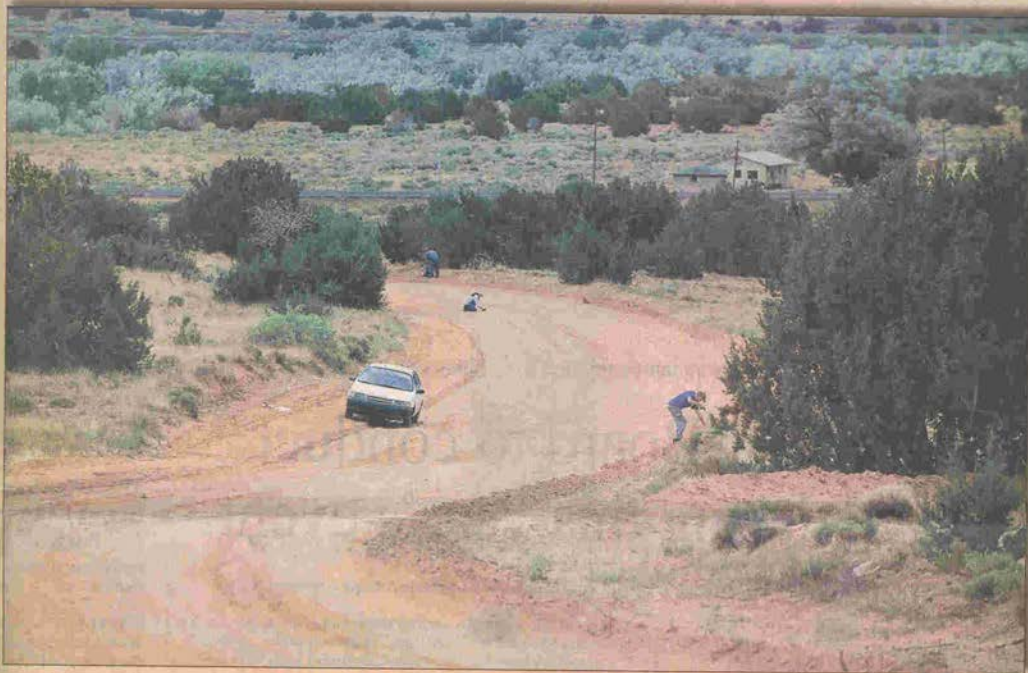
The cleanup ad-hoc committee meets 3 p.m. every Thursday at NABI.

Information: (928) 587-7599.

Fed up WITH trash



Brian Leddy/Independent



Brian Leddy/Independent

Above, Community members pick up trash on along the side of a road near Burntwater Tuesday. The initiative is part of an effort to address illegal dumping on the Navajo Nation. Top, James Foguth picks up cans along the side of a road in Burntwater Tuesday.

Burntwater trash pickup deemed a success

By Babette Herrmann
For the Independent

BURNTWATER — Verna Morgan, chair of the ad-hoc committee that spearheaded a community roadside trash cleanup in Burntwater, said the venture Tuesday was a success.

"I think we did a pretty good job," she said. "People will be proud to drive down the road."

Nearly 50 residents, including a handful of out-of-towners, came out to show their support by engaging in the back-wrenching work of plucking trash off the ground and out of shrubs.

The Native American Bahá'í Institute sponsored the event and provided trash bags, bottled water and an elaborate meal complete with fry bread to the crew post-cleanup.

Morgan said it was the first time in three years that a cleanup was initiated in the community, and the first time other religious organizations got involved in NABI's effort. Most of the churches involved picked up trash on their designated stretch of road the day prior to the

scheduled cleanup, Morgan explained, and it's an interfaith trend that she hopes will continue in future community improvement projects.

"Other denominations are connecting," she said. "It's working out really good."

Morgan also hopes that this event will inspire more youth to get involved with their community.

"I think a lot of the younger people need to participate in these events," she said. "We need to educate people."

James Foguth, 20, is one of those younger people trying to make a difference in his community by taking a hands-on approach from the early planning stages to completion of a project.

He's one of the leaders of NABI's junior youth group and believes there are three ways an individual can contribute to a community. The first two efforts, he said, could be a monetary gift or an organizational effort to assist a community post-disaster, such as hurricane and tornado relief. But, he feels, the most meaningful way to help a community

See Trash pickup. Page 5

Diné group tackles trash problem at grassroots level

By Babette Herrmann
For the Independent

BURNTWATER, Ariz.—Along a half mile stretch in the rural community of Burntwater, Ariz., an unnumbered BIA Road gives way to three smaller well-traveled dirt roads that lead to the ugly side of reservation life — illegal dumping. Heaping piles of twisted, rusted metal, worn-out tires and broken glass litters the ground in an otherwise picturesque tree-lined landscape. Each area has a theme of its own, whether it's a tapestry of tattered clothing mixed with broken toys or rows of rusted cans.

The proximity of each of the three dump sites is shocking, and to raise awareness of this ongoing problem, residents armed with garbage bags are taking matters into their own hands on a micro level by hosting a community roadside cleanup, sponsored by the Native American Bahá'í Institute Tuesday.

Local resident Verna Morgan, who leads the cleanup ad-hoc committee, said it's the second phase of a three-phase project in the remote hamlet to tackle the litter that dots the landscape and raise awareness about the even bigger issue of illegal dumping on reservation back roads. She has called upon local residents, businesses and churches from Sanders to Pine Springs on down to Houck to pick up trash along designated routes.

Anyone driving in the area can easily spot the boxes that once held a 12-pack of beer along with some of its empty cans nearby, or the broken bottles that once held booze, which have collected alongside the road over time. Some people even dump full bags of trash along the road.

"There are people who want change, something better than what is here," she said.

Morgan explained that the first steps toward making changes for a better community began more than a decade ago when NABI called on residents to tackle pressing issues such as the lack of a nearby well to haul water from. Next, they sought to bring residents into the 21st century by calling on the tribe to install underground pipelines so residents could have access to running water. The well is a done deal, but turning on the tap is still a pipe dream for many residents not living in tribal housing.

During the first phase of the cleanup campaign, NABI asked local children to draw a picture of what they thought of the littering, and to interpret their artwork. The committee learned from the children's in-depth perspective that they too were deeply impacted by the littering and dumping.

NABI and community leaders even sought the guidance of the Navajo Nation Environmental Protection Agency, and Morgan said officials encouraged the grassroots committee to move forward in mobilizing the community to address the problem. The NNEPA office, based out of Window Rock, is

providing trash bags for the cleanup.

As for dealing with the massive cleanup of the large dumping areas, that's a part of phase three and "we haven't got to that one yet," Morgan said.

Plans for the final phase, she said, could be accomplished in the near future by working closely with the Houck Chapter to set up a recycling program that pays residents for their recyclable items, instead of charging people for trash drop off. "A lot of these things that are dumped are recyclable," she said.

Currently, residents must stop at the chapter house, pay a nominal fee for each bag of trash, then unlock the gate and fling their trash over the top of a mammoth Dumpster that's usually full — and full of ravens tearing apart the bags and scattering the smelly contents to the ground. Next, they must pull out of the area, lock the gate behind them and return the key. As for disposal of some larger metal items, such as refrigerators and stoves, individuals must head southwest to Sanders and are generally paid pennies on the dollar for each item, usually enough for a gallon of gas or two.

Morgan admitted that residents, many of whom are poor and rely on government assistance, may feel they have no choice but to dump their trash. Many others resort to burning all of their trash, which releases toxins into the air.

Jerry Bathke, co-administrator of NABI for the past 14 years, envisions a progressive agenda for the community. With the science of trash continually evolving, he said, there may be a pilot program out there that experiments with sustainable waste disposal methods that the chapter house and/or community can take advantage of.

"There are some of these technologies out there. ... We can show the rest of the reservation that we can tackle this problem and create jobs in the area," he said.

Phase three also entails making educational presentations at the chapter house in a continued effort to raise awareness in the community, Morgan said.

And getting local youth involved is part of that effort. "This is their community," Alice Bathke, NABI co-administrator and Jerry's wife of 44 years, said. "They have to see the trash so they are aware that this could become their problem."

While Alice said she has not traveled to the large dumping hot spots in the area, as an enrolled member of the Navajo Nation, she grapples with Navajo teachings that call on her people to pray for mother earth, but she said, "Look at how we are treating mother earth."

Meanwhile, those who want to volunteer in the cleanup should meet at NABI by 8 a.m. Tuesday to pick up trash bags and to be briefed on what to expect that day. Volunteers should bring gloves, a hat and plenty of water.

Information: NABI (928) 587-7599 or Verna Morgan (928) 206-5669.

CHAPTER 4

CHAPTER 4

RESEARCH METHODS AND RESULTS: *TAKING CARE OF THE LAND – HUMAN-ENVIRONMENT INTERACTIONS* -- A TWO-TIER AGENT-BASED MODEL

INTRODUCTION

The collaborative exploration and the results derived during Phase-I and Phase-II (Chapter 3) were used to partially inform an agent-based model, the development of which, comprised the entirety of Phase-III. This Chapter will look at the research method of agent-based modeling and the results I derived from the application of my agent-based model *Taking Care of the Land – Human Environment Interactions* (TCL-HEI).

Following a brief background review of agent-based modeling that was covered more extensively in Chapter 2, below I revisit the relevant research questions pertaining to Phase-III. Then I proceed to evaluate the TCL-HEI agent-based model in two separate sections following the structure of the model itself, Tier-I and Tier-II.

The ABM platform-application used in my research during Phase-III was NetLogo (v4.1.3), designed and authored by Uri Wilensky out of Northwestern University. NetLogo's compiler language is written in Java and Scala and runs on the Java Virtual Machine (JVM) that partially compiles user code to JVM code. Due to its simplified user programming language and graphical interface, NetLogo was a first choice for my research. As noted by Railsback and Grimm (2009, p. iv) "NetLogo stands clearly ahead of the others as a platform for beginners and even for many advanced scientific models".

Method - Agent-based Modeling

As introduced in Chapter 2, agent-based modeling (ABM) is a field of computational modeling and is sometimes referred to as multi-agent modeling or individual-based modeling and dates back to the 1940s under the term cellular automata by von Neumann (Janssen, et al., 2006). However, in the context of my research involving a social-ecological system with emphasis on human environment interactions my focus is more on human behavior as it pertains to the environment. ABM's application to collective human behavior in the social sciences can perhaps be dated back to Thomas Schelling (1971) where he manually modeled the behavior of segregation using dimes and pennies. When looking at collective behavior through ABM three core themes have typically been prevalent in the first generation of ABM: spatial and temporal patterns, social contagion, and cooperation. More recent generations are beginning to address such areas as genuine predictiveness, experiential and experimental synthesis and internal representativeness of agents (Goldstone, et al., 2005).

A key feature of ABM is that it deals with system complexity and enables the modeler to explore this complexity in nonlinear ways resulting in outcomes that could not have been seen just through an analysis of the individual agents themselves. Instead, it is the autonomous interaction of the agents operating within simple heuristic rules under certain assumptions and towards a given objective in their given environment that may give rise to unexpected outcomes—in other words, the whole is greater than the sum of the parts. Emphasis is on the *agents* and not on statistical variables and this approach is fully in line with sociological theory (E. Smith, et al., 2007; Tubara, et al., 2010).

Van den Belt (2004) also explains that simulation modeling, being born out of system dynamics, provides a way to study system change and behavior through an identification of basic building blocks that help to explain core behaviors and where feedback loops and time lags help to identify and characterize the intricate relationships between a system's foundational building blocks. The modeling of these systems helps us to systematically understand these complexities and uncertainties involving time lags, feedbacks and nonlinearities (van den Belt, 2004, p. 3). As such, in altering time lags and scale parameters through the modeling process, policy makers are enabled ways of overcoming the disconnects of time and space by collapsing time and space into a time frame that will enable them to explore consequences of actions that would normally take place over long time periods that may not be in sync with institutional structures (Costanza, et al., 2001; van den Belt, 2004).

A particular method of model building is mediated modeling that is “based on system dynamics thinking but emphasizes the interactive involvement of affected stakeholders in the learning process about the complex system they are in. It allows a group of stakeholders to understand how seemingly small decisions may spiral a system onto an undesirable course. Such understanding provides opportunities to jointly design strategies to abate the negative spiral or to curb a trend into a more positive one” (van den Belt, 2004, p. 3). It is in essence a method of collaborative engagement and is a key method in my research. The fieldwork using this method is discussed in Chapter 3. Inherent in its design, mediated modeling aims for a collaborative team learning experience that elevates the shared level of understanding in a group and fosters a broad and deep level of consensus (van den Belt, 2004, p. 11). Further to the list of “why

model?”, van den Belt explains how mediated modeling helps to structure a group’s thinking and discussion, stimulates joint learning among a group of individuals with varying backgrounds, all of which lead to a new way of learning and building knowledge as addressed in the above section on truth, knowledge and reality.

Modeling has been used to meet many objectives and goals but perhaps the most applicable to my research is that of *usefulness* and *problem solving*. Grimm and Railsback (2005, p. 22) purport that, “the purpose of modeling is to solve problems or answer questions ... a model may address a scientific problem, a management problem, or just a decision in everyday life... to solving real-world problems, simplified models are the only alternative to blind trial and error ...”. In addition to finding utility for my model I believe it has to some extent contributed to one of the overarching goals of my research, that of serving as a means for capacity building, collaboration and raising the level of awareness of critical linkages between the environment and humans.

Research Questions

The following two research questions pertain specifically to my work in Phase-III that deals with agent-based modeling.

Q2 – What can an agent based simulation model on cooperative behavior, *Taking Care of the Land – Human Environment Interactions* (TCL-HEI), tell us about the dynamic relationships between individual and collective awareness to bring about sustainable cooperative action and change regarding illegal trash dumping – an issue that was adopted by participants in the local community and explored through photovoice, artvoice and the PSFA-CACB conceptual model?

Q3 – What might a theoretical *Regional Cooperative Clean-Energy Economy* (RCCEE) look like through the lens of the TCL-HEI agent-

based model depicting a clean-tech waste-to-fuels process as a sustainable entrepreneurial solution to create energy and jobs, and what are some likely positive and negative consequences for the regional environment and economy?

The agent-based model TCL-HEI has two levels of complexity. Tier-I is foundational and deals with key aspects of the social-ecological interplay between the environment and three types of participants (also known as *agents* in the world of ABM and more specifically *turtles* in the world of NetLogo, one of many ABM platforms and the platform I use). Tier-II builds upon Tier-I and presents a new layer of complexity with the introduction of certain economic variables and discusses a theoretical conceptual model pertaining to a *Regional Cooperative Clean-Energy Economy*.

TCL-HEI (Tier I & II) along with the RCCEE conceptual model, represents a semi-empirical and theoretical sustainable entrepreneurial solution to addressing the issue of illegal trash dumping that emerged during the Phase-I exploration using photovoice and artvoice. It is during the entire collaborative process that an awareness of local issues gives rise to collective action culminating in a mitigation of environmental degradation and theoretically, gives rise to jobs, wealth creation, prosperity and overall human dignity. Further, with assistance from administrators, officials and policy makers at the Chapter, Agency and National levels on the Navajo Nation it is my hope that such a model might assist in offering a more holistic and pragmatic approach to understanding better the complexities of social-ecological systems on the Navajo Nation that deal with solid waste and the environment.

MODEL 2 TIER-I: *TAKING CARE OF THE LAND* – *HUMAN-ENVIRONMENT INTERACTIONS*: THE ENVIRONMENT, ILLEGAL TRASH DUMPING, CONSULTATION, AND COOPERATION

Phases I and II of the participatory field exploration in Houck, Arizona set the direction and focus of the agent-based model that was designed. The title, *Taking Care of the Land*, came informally from one of the participants in the field during a consultation gathering. Partially basing the model on field interaction takes the model out of an entirely theoretical domain and gives it an empirical foundation. Further, actual field data was used to inform and parameterize key aspects of the model such as population density and probabilistic consultation outcomes. This latest Tier-I version (v9.0) of the model came after numerous trial and error modeling attempts—sometimes with the entire underlying code having to be rewritten several times in order to come to a working model that behaved in a way that I felt could best represent the ideals of the research (Appendix 4.1). However, as most modelers might attest, a model is merely a reflection, a glimpse, of some aspect of the reality being observed. No model can serve as a true and complete representation of its objective. A balance has to be struck between representation and simplicity or else the model becomes intractable. This is something I began to really experience with the economic application in Tier-II. Further, there is an aspect of art in modeling and as such there is a degree of creative emanation that goes into the model by the modeler. This individuality makes the study difficult to replicate unless the researcher chooses to use the original model design. One way to assist with the science behind replicability is to present the model design in a consistent format and one such format is the Overview, Design, and Detail (ODD) protocol format (V. Grimm et al., 2006). For a

more detailed discussion on the background of agent-based modeling see Chapter 2. Details pertaining to my model using the ODD format are set out below.

Tier-I: Overview, Design and Detail

ODD-Purpose:

Tier-I of the model was designed to explore interactions of human behavior and the environment, specifically evaluating peoples' interaction and influence upon each other regarding the behavior behind illegal trash dumping and environmental clean-up practices.

ODD-Entities, State Variables, and Scales:

Tier-I has four entities: people, places, square patches of land and a global environment. The people are discrete mobile units of three types (breeds) to which I assigned a color for further distinction: *uncooperatives* (red), *cooperatives* (green) and *environmental stewards* (turquoise). The color assignment is indicative of action and value. Red signifies a stop or unwanted action, green signifies an action that is good and that should be continued while turquoise is indicative of having attained a high station of worth and value and is a color very dear to the Navajo heart and one that is exhibited frequently through art and the wearing of jewelry. *Uncooperatives* have a negative value orientation towards the environment and choose to dump trash illegally. While in reality there may be a plethora of reasons why an *uncooperative* may choose to dump trash illegally, I needed to simplify the model by isolating the *uncooperative* illegal trash dumping behavior to a lack of environmental concern driven solely by economics, i.e., wherever it is most economical to dump trash regardless if it is illegal. However, for

simplicity in Tier-I, economics is not a factor but will be introduced in Tier-II. *Cooperatives* have a positive but low value orientation. They also have a moral sense of right vs. wrong when it comes to dumping trash. As such, they will not dump trash illegally but nor will they spend time or energy to clean up the environment. *Environmental stewards* have a high positive value orientation towards the environment and only dump trash legally. They expend time and energy to clean up the environment. Another one of the entities are places. These serve a nominal purpose in Tier-I as a place towards which a person is moving. The state variables are specific to the entity or breed. The state variable for *uncooperatives* is that they own the behavior of illegal trash dumping. The state variable for *environmental stewards* is cleaning. Patches make up a rectangular grid landscape of 819 x 464 patches and each patch has one dynamic state variable: its cleanliness, i.e. its degree of garbage pollution and one static state variable, roads. The road network is an overlay onto the topographical landscape and determines boundaries for directional movement. Each time step (tick) represents a day, i.e. the duration of 365 ticks represents a period of a year. The time scale in the model is not representational to movement. Movement is simply a function to create interaction. However, the timescale is representational of the frequency of trash dumping that is a key social-ecological characteristic the model seeks to explore. Trash dumping occurs on a weekly basis and is typical of municipal trash disposal and collection patterns throughout the United States (EPA, 2009) and is also representative of much of the Navajo Nation. The spatial resolution of the landscape consists of a 819 x 464 patch grid for a total of 380,016 patches representing the actual landscape of 4.88 mi (east-west) by 7.52 mi (north-south) for a total of 36.7 mi² (23,496 acres). This equates each patch to represent

an area of just over 2,692 ft². A sample of the view window taken from a simulation run is depicted in Fig. 4.1. The general area of Burntwater and the Native American Baha'i Institute (NABI) are located in the top-left quadrant; the Houck Chapter House is in the bottom-right quadrant; and, the Querino Trading Post is in the left-lower quadrant—all represented by black dots.

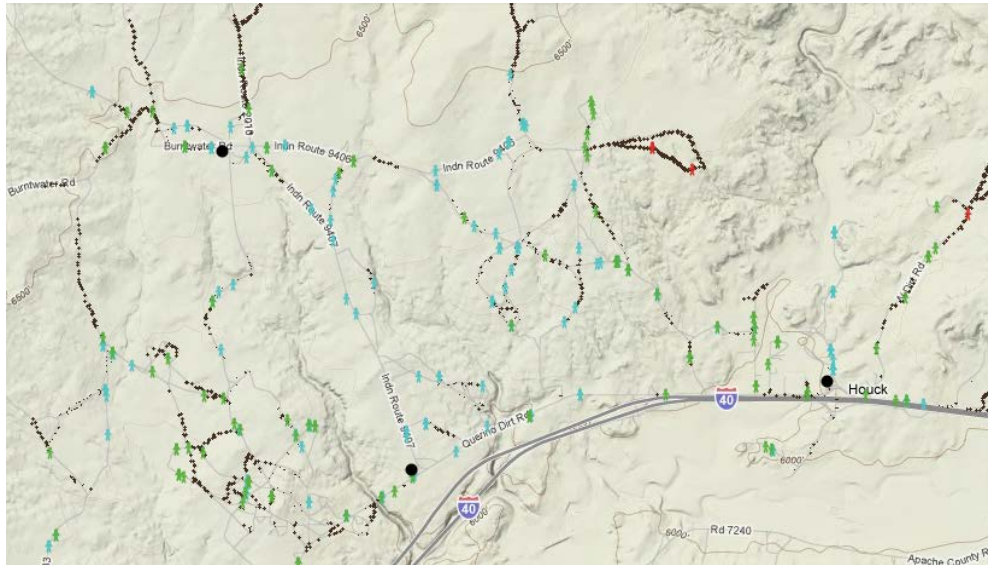


Fig. 4.1 ABM TCL-HEI Sample View with Places (●)

ODD-Process Overview and Scheduling:

The initialization process (see below) populates the model with *uncooperatives*, *cooperatives* and *environmental stewards* (counts to be chosen by the researcher) with random distribution of each along the road network.

Dynamic processes include people moving, dumping, cleaning, sensing other people, consulting/influencing other people. The people are asked to move along the road network in search of the nearest of the three places. This gives a sense of purpose and direction. Peoples' encounters, their interaction (sensing and reacting), and their environmental action (dumping and cleaning) are processed in sequential order. During

the ‘consult’ routine people’s encounters with each other is dependent upon their relative values (see below) and the nature of the encounter will determine the response outcome that is scheduled to update after the ‘consult’ routine executes by placing each person’s outcomes into a temporary hold file.

ODD-Design Concepts:

Outcome and Expectation: The Tier-I model objective/outcome is an emergent sustainable behavior and action towards environmental cleanup. This outcome is influenced by randomness such as movement, direction and the interaction of several model variables like: how many *environmental stewards*, *cooperatives* and *uncooperatives* will be interacting; the probabilistic adaptive capacity of each person, namely the chance of becoming an *environmental steward*, a *cooperative* or an *uncooperative*; and, from the influence of a person’s persuasion capacity that is a determinant of sphere of influence.

Environmental Value (EV) and Persuasion Value (PV): Dumping/cleaning behavior is based on the value of each person’s environmental value (EV) that is initially assigned as a random selection from a range. Being positive indicates value orientation and the quantity is indicative of EV strength. *Environmental stewards* have a positive EV orientation with the highest of the ranges at [3 4 5]. *Cooperatives* have a positive to neutral EV orientation with less EV strength. Their range is initially set at [0 1 2]. *Uncooperatives* have a negative EV orientation and are initially assigned an EV range of [-3 -2 -1]. A change in EV orientation implies a change in behavioral direction when a person gains or losses in sufficient magnitude to put them into a new range. *Environmental stewards* have a unique quality pertaining to their EV where the absolute

value of their EV sets the radius (eradius) of the area they clean when encountering a patch of trash. For example an *environmental steward* with an EV=4 will have an eradius=4 and when encountering a set of 10 patches that are assigned as polluted, it will clean 4 of those patches in a given cycle. EV is dependent on people to people and people to group interaction and stochasticity (see below). Adaptive behavior that results from these interactive outcomes is based on the understanding (implicit in the model) that people's behavior is self-reinforcing and that people respond positively or negatively to the strength or charisma of other people and their behaviors and to positive group interaction as supported by collaborative engagement theories and aspects of a theory of community-based social marketing (McKenzie-Mohr et al., 1999).

Each person also has an initial persuasion value (PV) that determines their ability to influence others with whom they encounter. The initial settings for all people are randomly pulled from a range [4 6 8 10]. The absolute value of PV determines the radius of influence (pradius).

Objectives, Learning, Prediction: An *environmental steward's* objective is to influence other people with whom it encounters who have a lower PV value than itself. *Environmental stewards* also have an objective to clean up trash when it is encountered. Their learning from encounters with other people is adaptive but only in a positive direction in favor of environmental stewardship. Given their high environmental ideals, it is rare to unlikely that an *environmental steward* would change environmental values easily. This is consistent with the Cognitive Hierarchy Model of Human Behavior that states that values “represent single, stable beliefs that individuals use as standards for evaluating attitudes and behavior...Values are not specific to particular objects like ...

the environment...values are the most central component of a person's belief system, whereas attitudes vary with respect to how strongly they are held" (Vaske et al., 2006, p. 24).

Uncooperatives' objectives are self-centered and they care only for themselves. They have a negative environmental value orientation but their actions are driven solely by economics and can be said to have more of an attitude-based decision making process. They will not spend extra money or fuel to travel to a legal dump. The dumping mechanism is a variable the researcher can set, e.g., if set on 7 then a dump will occur once in 7 days. *Cooperatives* have an environmental value orientation that is either positive [1 2] or neutral [0] to begin with. They will not dump illegally. As is the case with all people types, their environmental orientation (behavior) will change in the direction of the person with whom they engage if the absolute value of the PV of that person is stronger. Alternatively, if their PV is stronger than that of an *uncooperative*, they will influence the *uncooperative's* EV. An *uncooperative* can learn (be influenced) by another *uncooperative* and gain a stronger negative EV or learn from a *cooperative* or *environmental steward* with a higher EV. An *uncooperative* whose EV becomes zero, has a values shift and adapts into a *cooperative*. The predictive outcomes of these interactions are subject to the initial static and stochastic variable settings and random generation.

All people types have an objective to dump during a dump cycle when 'dump?' is switched on. *Environmental stewards* and *cooperatives* dump legally and *uncooperatives* dump illegally. Because the intent of the model is to evaluate behavioral interactions and how these interactions lead to environmental outcomes of legal vs. illegal trash dumping and subsequent cleaning, I decided to simplify the model by not establishing formal trash

sites on the landscape. The view depicts dumping along the roadside; however, the statistics capture cumulative changes to how legal and illegal trash volume balances are reported in tons. The visual of dumping illegally along the road is misrepresentative from the reality on the ground however, during feedback sessions with some of the Navajo it proved to be a powerful visual depicting how the environment can be polluted and that it is not too unrealistic as there are many random roadside locations where illegal dumping has occurred.

Sensing: People sense and respond to their patch, sensing the road boundaries; sensing if they have reached a road intersection; and sensing for an encounter with another person. All people sense the presence of another person sharing a patch or patches within their pradius of influence and interact.

Interaction: Interaction amongst people can result in a values change. An encounter is based on relative pvalues with the higher value influencing the lower value. The affect on the EV of the person being influenced is based on the mathematical difference between the respective PVs. The PV difference is added to the impacted person's EV. People interact with their patch by knowing they need to stay on the road and, by either cleaning or dumping that patch. An *environmental steward* will interact with a patch that is polluted by cleaning it up if the 'clean?' switch is on. An *uncooperative* will dump illegally on a patch during a dump cycle.

Stochasticity: This is used to influence the parameter of people-to-people encounters where there is a given probability that the person with the higher PV will influence the person with the lower PV. In other words it cannot be assumed, *ceteris paribus*, that a higher PV can always influence a lower PV. This logic is consistent with

the perceived reality of a complex social-ecological system in which there may always be the chance of some unforeseen extenuating circumstance that prevents one from being influenced to change fundamental patterns of action on a long-term basis. So if the variable is with a probability at 75%, then 75 out of 100 encounters will result in an environmental value change in an order of magnitude set by the PV differential of the two people in the encounter. Probabilistic data from the field study was used to inform the model and these findings were used in the baseline trials (see below).

Observation: To allow observation of landscape change (restoration or degradation), a specific environment window measures the overall frequency of clean-up and dumping. This can be seen for example in Fig. 4.1 above. All people types will dump trash. The difference is that *uncooperatives* will dump illegally impacting the landscape and *environmental stewards* and *cooperatives* will dump legally impacting the landfills. There are four plots and numerous supporting monitors. The ‘Cooperative Behavior’ plot tracks the population change between the three people types. The corresponding monitors show their respective counts and values. The ‘Trash Dumped’ plot tracks the volume of legal and illegal trash and the total being the sum of the two. The ‘Landscape’ plot shows the portion of the landscape as seen in the view that is being polluted or cleaned. This is not exactly representative of the trash statistics as it is based on patches polluted and not an actual weight volume of trash. However, it serves to be a powerful visual indicator depicting the polluting and cleaning process. The corresponding monitors track the percentages. The ‘Landfill Waste’ plot shows what portion of trash is heading off to the landfill site and in the Tier-I model 100% of legal trash goes to the landfill where this

may not be the case in the Tier-II model discussed below. The other monitors show the waste stream totals and percentages.

ODD-Initialization:

The topography of the landscape (the road network) is initialized when the model starts. Two kinds of landscapes are used in different versions of the model: (1) a simple road network and (2) the topography of a real study site, imported from a file containing topographic values for each patch. A landscape switch allows for a change of scenery from a basic map to a terrain view or a satellite imagery view—all for aesthetic value only and a feature that some of the participants liked. The people are initialized by creating the number set by the variable counts and setting their initial location at random locations on the road network. People's EVs and PVs are set in accordance with initial range setting values as discussed above.

ODD-Input Data:

The environment is assumed constant, so the model has no external input data.

ODD-Sub-models and Switches:

There are no sub-models; however, this is something that future researchers might wish to look at such as a sub-model routine running weather to add a layer of complexity. Weather is a factor that impacts transportation, a feature in the Tier-II model. However, due to complexity and limitations with computing capability I had to forgo this option. People and places can be hidden with their corresponding switch. There are also switches to turn on the 'dump' and 'clean' routines.

ODD-Simplifying Assumptions:

Simplicity is a key rule of thumb in modeling and requires making realistic but simplifying assumptions. For example, the Navajo Nation has illegal trash dumping law enforcement but because it is weak to nonexistent in some areas, the model does not account for this action but rather for the non-action and resulting impact on behavior. Weather plays a big part in the area due to the dirt roads making them virtually impassable during certain periods. However, to simplify the model this is not an incorporated feature. Another assumption being made pertains to scale. To simplify and provide for a better visual interface with the model, each patch color is changed if it is dumped on, that is not scale realistic. In reality it would not be unreasonable to have an *uncooperative* dumping the equivalent of a Ford F-150 pickup truck load that is about 30 sq. ft. and as such it would take about 100 of these truck loads to fill a 2900 sq. ft. area about the size of one patch. However, the view is used mostly for aesthetic visualization purposes whereas the numbers being reported and monitored are what are being used in the research analysis. Another simplification pertains to people's true psychology and behavior that would virtually be impossible to capture in such a simple ABM. For example, people may be motivated to dump in various locations, new locations, only at night, at very far distances, etc. However, I believe the simplification measures taken in the model do not undermine the true value of the model in explaining and portraying the very real issue of illegal trash dumping that has been empirically verified. Nor have such simplifications impaired the collaborative value such a model is having with showing how the work done in Phases I and II can be portrayed in a visual and high-tech

manner—both are important aspects to the exploration focus and research question for this Phase-III.

Results and Learnings

Tier-I of the model seeks to explore the second research question:

Q2 – What can an agent based simulation model on cooperative behavior, *Taking Care of the Land*, tell us about the dynamic relationships between individual and collective awareness to bring about sustainable cooperative action and change regarding illegal trash dumping – an issue that was adopted by participants in the local community and explored through photovoice, artvoice and the CACB model?

The creation and sharing of the agent-based model *Taking Care of the Land – Human Environment Interactions* (TCL-HEI) has lead to an additional collaborative element in the overall tri-phase approach to exploring *collaborative adaptive capacity building*. On the one hand, it has been the culmination in using the data gathered during Phase-I and Phase-II. With one-on-one feedback from participants, it has inspired and even awed some of the Navajo and I am hoping that the model will serve a purpose as a tool for local and regional Navajo Nation officials further to explore the issues behind illegal trash dumping. Tier-I is designed to depict plausible interaction in the environmental setting of the Houck Chapter along the rural road landscape. It is through these encounters that outcomes have either a negative or a positive impact on the environment depending on a person's environmental value orientation and strength as well as their ability to persuade others to their point of view. Collectively, through the tri-phase process the community of participants gradually began to understand and see a vision and purpose to the research as it evolved. This particularly became known in

Phase-II during the game playing (see Chapter 3) and how the game gave rise to the road network that was used in the ABM. Another feature of collective action and awareness tied to the ABM came from a group focus gathering where we explored potential responses to encounters between someone who dumps trash illegally and someone who is environmentally conscientious. The results from this focus group were used to direct the parameterization of the baseline trials for both Tier-I and Tier-II. Although this was a Phase-II activity I chose to share these results here as they are particularly relevant to the ABM (Table 4.1). At the time of the focus group, the concept of three types of people had not yet emerged. This came later during the model development phase. During Phase-II, there were simply two types of people a cleaner and a dumper. However, the key data that I was able to extrapolate from the focus group was that if a cleaner were to cross paths with a dumper how likely would it be that the cleaner could influence the dumper to change his/her behavior. Although I presented three alternative scenarios revolving around location (on the road, in the Chapter House, in a group) the scenario pertaining to an on the road encounter was the most relevant and meaningful. The cumulative result I derived from this inquiry was that the group felt there was about a 38% chance a cleaner could influence a dumper to stop their activity. In a reverse scenario, the group felt there would be no more than a 10% chance a dumper could influence the cleaner to join in on the illegal activity of dumping along the road. The final encounter is where there were multiple people together as cleaners engaging a dumper. Here the group felt there would be an 85% chance this could happen. As the ideas for the model progressed into having three people types, I referenced the *environmental stewards* with their high EV orientation to take the place of a group of cleaners.

Table 4.1 Probability of Changing Dumping Behavior

ENCOUNTER I: Cleaner meets Dumper along road side													
ENCOUNTER II: Cleaner meets Dumper in neutral setting like Chapter meeting													
ENCOUNTER III: Collective of multiple Cleaners influence on Dumper's activity													
% Chance that:													
A) Cleaner influences Dumper to not dump?													
B) Dumper will influence Cleaner to join D's dumping activity?													
C) Neither will influence each other?													
SCALE:	0	1	2	3	4	5	6	7	8	9	10	% Cnt Prob.	
I-A		3	1	1	1	1		3				10	
	0%	30%	10%	10%	10%	10%	0%	30%	0%	0%	0%	100%	
	0	3	2	3	4	5	0	21	0	0	0	38	38%
I-B		10										10	
	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	
	0	10	0	0	0	0	0	0	0	0	0	10	10%
I-C									5	5		10	
	0%	0%	0%	0%	0%	0%	0%	0%	50%	50%	0%	100%	
	0	0	0	0	0	0	0	0	40	45	0	85	85%
II-A		3	1	1	1	1		3				10	
	0%	30%	10%	10%	10%	10%	0%	30%	0%	0%	0%	100%	
	0	3	2	3	4	5	0	21	0	0	0	38	38%
II-B		10										10	
	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	
	0	10	0	0	0	0	0	0	0	0	0	10	10%
II-C									5	5		10	
	0%	0%	0%	0%	0%	0%	0%	0%	50%	50%	0%	100%	
	0	0	0	0	0	0	0	0	40	45	0	85	85%
III-A									5	5		10	
	0%	0%	0%	0%	0%	0%	0%	0%	50%	50%	0%	100%	
	0	0	0	0	0	0	0	0	40	45	0	85	85%
III-B		10										10	
	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	
	0	10	0	0	0	0	0	0	0	0	0	10	10%
III-C		5	5									10	
	0%	50%	50%	0%	0%	0%	0%	0%	0%	0%	0%	100%	
	0	5	10	0	0	0	0	0	0	0	0	15	15%

To test the stability of TCL-HEI Tier-I and to establish a baseline of indicators, five randomly generated seeds were created to run five trials. Using a random seed that is stored allows for trials to be rerun in exactly the same order each time to get exactly the same results provided the same version is used, the code is not altered and all variables remain the same each time. Each trial was stopped at 365 iterations (one year). The population distribution was set at $n=250$ representing heads of households as it is assumed just one person is in charge of dumping the trash per household. With an average 3.39 people in each household (City-data, 2010) this yields a total representative trash accumulating population of around 850 that is an estimate below the estimated total population of 1083 in Houck (City-data, 2010) as my research area did not comprise the entire area of Houck. On any given day, this population base would then be expected to generate an estimated 1.7 tons of trash assuming 4 lbs per person per day is generated. Estimates for a national average in the U.S. is around 4.3 lbs / person / day (EPA, 2009) while the Helgoth consultants estimated 4.73 lbs / person / day on the Navajo Nation back in the year 2000 (Helgoth, 2000). I believe a more conservative number of 4 lbs is quite adequate for the purpose of this model and might be more indicative of consumption habits for a lower income group. Key data from these baseline trials are presented below: a section of trial #1 ABM interface (Fig. 4.2) as well as the data from all five trials (Table 4.2).

These initial Tier-I trial settings are for the most part hypothetical to set up the baseline trials. The empirical data used to inform these trial runs include the approximate heads of households, the focus group percentage chance settings, the topographical landscape choice, the road network, and the extrapolated dump setting of 4 lbs per person

a day as discussed above. Given the concerns for illegal trash dumping I arbitrarily set *environmental stewards* low and *uncooperatives* high to hyper-sensitize the model run in favor of illegal trash dumping at the outset. The variable settings and results are as follows:

Tier-I Baseline Trials

#Env Stwds	25
#Cooperatives	75
#Uncooperatives	150
Total Heads of Households	250
Chance to be Env Stwd	85%
Chance to be Cooptv	38%
Chance to be Uncooptv	10%
Dump?	on
Dump once per	7 days
Dump trash/person	4 lbs
Clean?	on
Clean once per	7 days
Clean trash/person	3 lbs

A key aspect of these baeline trials is that the model performed as expected with *environmental stewards* (49%) and *cooperatives* (42%) sharing the majority of activity on average (Table 4.2) ending with populations having a greater influence on behavior and hence environmental action. The model remained stable and there were no significant or wild variations between trials. Given this semi-hypothetical scenario, the total trash generated on average over the course of a year came to 617 tons of which a significant amount (23%) was illegal dumping. Landfill accounted for 100% of total legal trash as there were no recycling or clean-energy programs running on the Tier-I model.

Baseline Trial # 1 RS: -5602708320633769

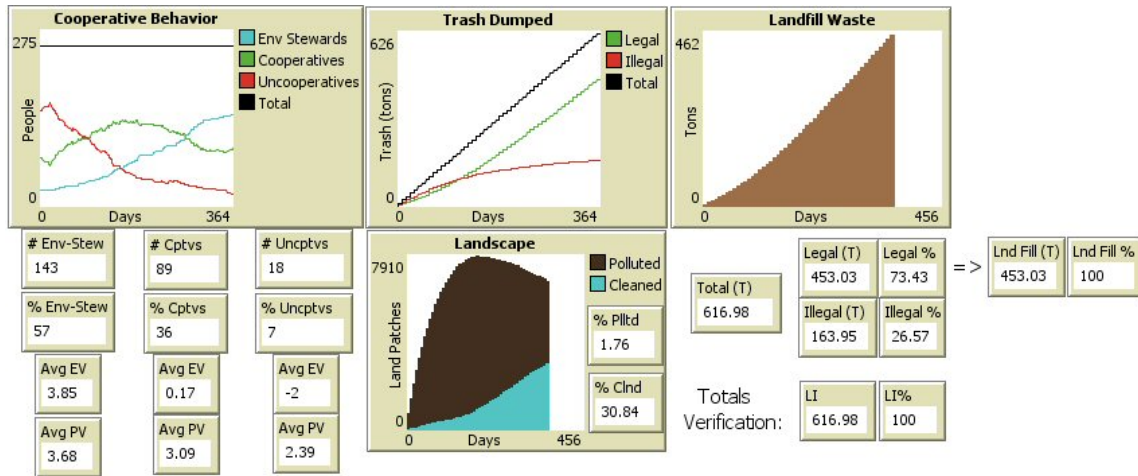


Fig. 4.2 TCL-HEI Tier-I (v9.0) 5 Baseline Trial #1 @ 365

A key feature depicted in the Cooperative Behavior plots are the transition points between *environmental stewards*, *cooperatives*, and *uncooperatives* and between legal and illegal trash dumping in the Trash Dumped plot. As seen from the above plots (Fig. 4.2) and the representative data (Table 4.3) *cooperatives* exceeded *uncooperatives* at an average iteration of 86 and shortly after that there was a transition in dumping behavior where legal activity excelled illegal activity at iteration 119. What is significant about these transition points is that they represent change and feedback in this semi-hypothetical social-ecological system and in the case of these five trials it is all positive change that excels the system towards a more desirable state. It could be argued that at the outset in all five trials the system is in an undesirable state where uncooperatives exceed either *cooperatives* or *environmental stewards* and that the system hits a tipping point (119 on average) when legal activity begins to exceed illegal activity indicating a shift in behavior and action and a more desirable regime basin emerges in which the system finds itself. This point is discussed more fully in Chapter 5.

Table 4.2 TCL-HEI Tier-I (v9.0) Baseline Random Seed Trials @ Day 365

	Trial #1	Trial #2	Trial #3	Trial #4	Trial #5	Avg	Med
Total Hd Hshld	250	250	250	250	250	250	250
# Env-Stew	143	98	125	136	115	123	125
%	57	39	50	54	46	49	50
Avg EV	3.85	3.71	3.78	3.67	3.86	3.77	3.78
Avg PV	3.68	2.99	3.03	2.25	2.61	2.91	2.99
# Cptvs	89	132	103	82	117	105	103
%	36	53	41	33	47	42	41
Avg EV	0.17	0.17	0.21	0.13	0.09	0.15	0.17
Avg PV	3.09	4.06	4.39	3.59	4.7	3.97	4.06
# Uncptvs	18	20	22	32	18	22	20
%	7	8	9	13	7	9	8
Avg EV	-2.00	-1.90	-2.09	-1.97	-2.33	-2.06	-2.00
Avg PV	2.39	2.95	4.55	4.69	4.56	3.83	4.55
Ttl Trash (T)	617	617	617	617	617	617	617
Lgl Trash (T)	453	466	467	431	437	451	453
Lgl Trash (%)	73	76	76	70	71	73	73
Illgl Trash (T)	164	151	150	186	180	166	164
IllglTrash (%)	27	24	24	30	9	23	24
Lnd Fill (T)	453	466	467	431	437	451	453
Lnd Fill (%)	100	100	100	100	100	100	100

Median scoring:

2498.17	2512.28	2515.08	2477.04	2464.22	2493.36	2495.39
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Highlighted score represents trial closest to the median

Table 4.3 HCL-HEI (v9.0) Transition Comparatives between Trials (at iteration pts)

	Trial #1	Trial #2	Trial #3	Trial #4	Trial #5	Avg
Cptvs > Ucptvs	89	68	71	85	119	86
L-trash > I-trash	113	92	106	134	148	119
EnvStw > Ucptvs	155	164	152	167	165	161
EnvStw > Cptvs	274	-	285	269	-	276

Seeing that the model was stable during the baseline trials I then began to explore beyond these parameters. Using trial #1 for its representative overall median values (Table 4.2) I ran the model out beyond one year to 1095 iterations (Fig. 4.3). Again the model performed well and to my expectations where *environmental stewards* dominated

the system given the high probability (85%) that an *environmental steward* could convince others to change their behavior. At the end of the run there was only one *uncooperative* left and the observable reason for the resistance to change could be explained by a combination of that person's relatively high average persuasion value

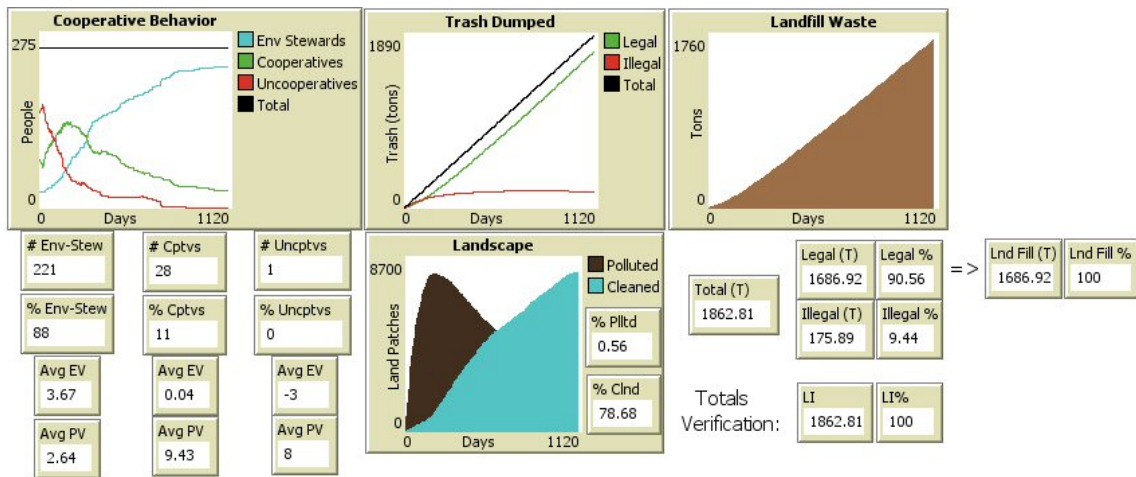


Fig. 4.3 TCL-HEI Tier-I (v9.0) Baseline Trial #1 @ 1095

(Avg. PV = 8) in comparison to the average PV of *environmental stewards* (PV = 2.64) and to this person being on a remote road loop with minimal traffic. Movement is a feature that perhaps will be enhanced in future versions; however, I am able to justify the current movement and resulting outcomes on the basis of existing limitations to transportation and communication in the more rural areas of the Houck Chapter. The remaining 28 *cooperatives* were in accessible locations but they retained dominant PV values with an average PV = 9.43 making them not willing to change their environmental value orientation from their current positions. Again, this is not a too improbable outcome as discovered during Phase-II of the exploration where many participants expressed a desire to want to take care of the land but gave a number of reasons why they could not or would not get involved in trash cleanup such as “too costly”, “don’t have

gloves” or “I’m afraid of big rats”. Furthermore, at 1095 iterations less than 1% of the landscape remained polluted and of the polluted landscape 78% had been cleaned up due to the high presence of *environmental stewards*.

Further questions arose from these results such as how does the model play out at a different clean scenario and would this be realistic. Based on national EPA data as discussed above, I was able to extrapolate that an estimated average of 4lbs per person is generated each day. However there was no readily available data to know how much, if any, trash gets cleaned up on a regular basis so I explored this further using the model (see below). Another area that peaked my interest was to know that if the Tier-I model is showing a shift into a desirable regime basin as discussed above then how does this represent the reality on the ground based on casual observation? Is such a shift happening too early in the model and if so why? Why does illegal trash dumping appear to be persistent in reality and what model variables might allow for such a scenario in Tier-I? One possible answer in the TCL-HEI Tier-I model is that the assumptions about the probability of persuading another individual to alter their behavior are over stated. Perhaps the true reality is somewhere lower. Or perhaps the *environmental stewards* on the ground are fewer than being portrayed in the model. This does open up future study possibilities to make more indepth inquiries with multiple focus groups and a rigorous statistical survey of the area where time and money might permit. For my results, I am able to explore and discover this notion with hypothetical trials or scenarios to see how outcomes might differ with a change in these variables. This type of scenario/sensitivity analysis is something that policy makers and officials might engage in using this model but populated with data to fit more tightly a given situation or Chapter.

Discovery

Scenario 1: Using Trial #1 from the baseline runs I first addressed the question of transitioning from illegal trash dumping to legal trash dumping. As noted by the baseline trials, on average, the Tier-I model transitioned at around 119 iterations and then continued on towards an improving state of affairs. However, the reality on the ground would suggest otherwise given that illegal trash dumping is a persistent problem as evidenced with the Phase-I results of this research (Chapter 3). Using TCL-HEI Tier-I, I explored two possible explanations for this discrepancy. I first looked at the percentage chance variables to see if perhaps these were unrealistic at the outset, then I looked at the initial start up distribution between people types and finally I looked at a combination of both. After running multiple combinations I settled on the below combination of variables that might suggest a more realistic situation than the semi-hypothetical baseline settings used above; yet, again in the absence of rich survey data this is just suggestive based on my observations over the past year and half.

Tier-I Discovery Trial #1A

Random seed	-5602708320633769
#Env Stwds	5
#Cooperatives	195
#Uncooperatives	50
Total Heads of Households	250
Chance to be Env Stwd	25%
Chance to be Cooptv	5%
Chance to be Uncooptv	25%
Dump?	on
Dump once per	7 days
Dump trash/person	4 lbs
Clean?	on
Clean once per	30 days
Clean trash/person	20 lbs

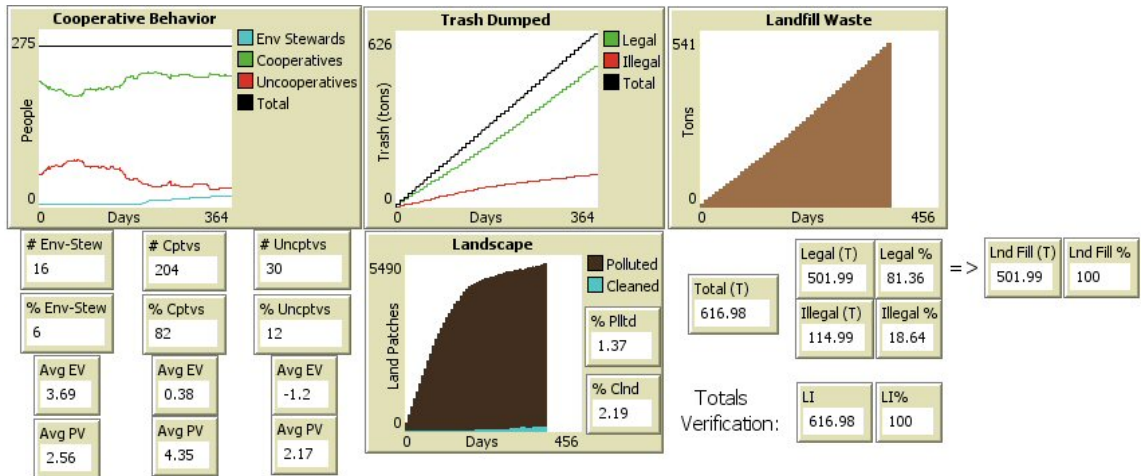


Fig. 4.4 TCL-HEI Tier-I (v9.0) Discovery Trial #1A @ 365

The Cooperative Behavior plot in Fig. 4.4 shows a proportionately higher population of *cooperatives* (204#, 82%) suggesting that most people want to cooperate and do the right thing however there remain 12% of *uncooperatives* who continue on a path of environmental degradation. It also depicts *environmental stewards* (16#, 6%) who are willing to spend time and energy to clean up the environment. The percentage of illegal trash dumped after a year is below 19% at the end of 365 iterations. As time progressed there was a gradual awareness of the need to clean up the landscape as indicated in the late rise in *environmental stewards*. This hypothetical scenario depicts a slow start to change in an environment with no other influences such as politics, economics or the law. In this scenario the undesirable state of the social-ecological system could be considered that of the presence of illegal trash and the continuance of this behavior. A transition to a more desirable state would require a cessation of this activity and transformation of behavior from *uncooperative* to at least *cooperative*.

I then asked what if there was a turn for the worse in economics from rising gas prices or a drop in tourism trade to where the *uncooperative's* motives for dumping

illegally would be more persuasive to others and the *environmental stewards* would have a hard time trying to convince others to join them. In such a scenario I dropped the probability of the *environmental stewards* to 5% and raised the probability of *uncooperatives* to 50%. The variables settings for Discovery Trial #1B are as follows.

Tier-I Discovery Trial #1B

Random seed	-5602708320633769
#Env Stwds	5
#Cooperatives	195
#Uncooperatives	50
Total Heads of Households	250
Chance to be Env Stwd	5%
Chance to be Cooptv	5%
Chance to be Uncooptv	50%
Dump?	on
Dump once per	7 days
Dump trash/person	4 lbs
Clean?	on
Clean once per	30 days
Clean trash/person	20 lbs

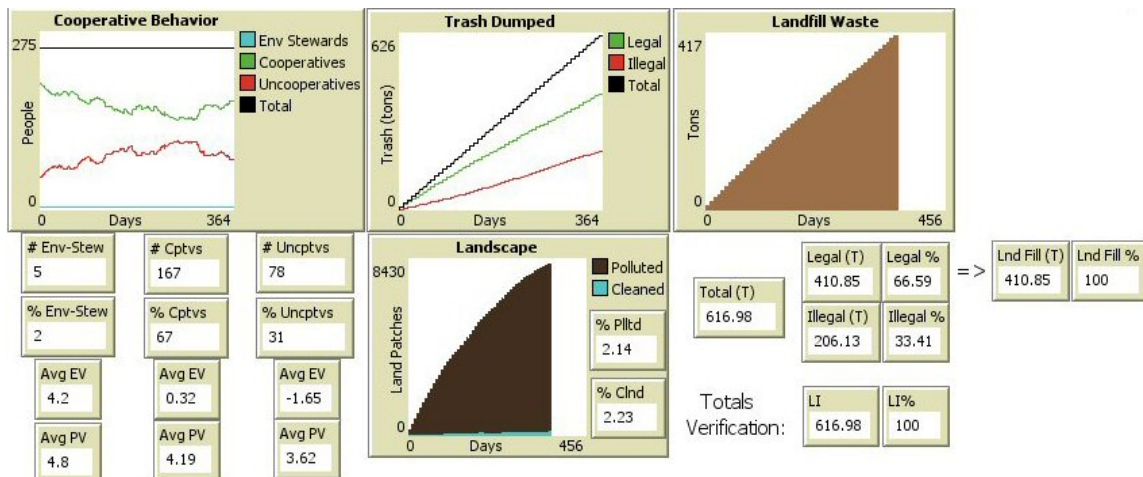


Fig. 4.5 TCL-HEI Tier-I (v9.0) Discovery Trial #1B @ 365

As depicted in Fig. 4.5 there is a gradual worsening of the environment with illegal trash accumulation reaching 33% after a year compared to 14% in Trial #1A.

Further, due to the lower probability of being able to convince others, the *environmental stewards* were unable to make an impact.

I then asked what if the reverse were true or perhaps if the local/regional authorities were able to implement an incentive program such as the development of an entrepreneurial business cooperative that might empower more activity on the part of the *environmental stewards* and change behavior and action of *cooperatives* and *uncooperatives*, what might this look like? In one scenario it could look something like the focus group probabilities with *environmental stewards* at 85%, *cooperatives* at 38% and *uncooperatives* at 10% as seen in the above baseline trials where legal trash dumping ended up with a strong finish at 365 iterations despite starting out with 150 *uncooperatives*. However, I chose to take a more conservative path using lower probabilities at 50%, 25% and 5% respectively. Another change I made for this positive outlook scenario was to increase the trash-clnd/prsn to 40lbs on the assumption that due to increased incentives *environmetnal stewards* are likely to clean more trash. The variable settings for this Discovery Trial #1C are as follows.

Tier-I Discovery Trial #1C

Random seed	-5602708320633769
#Env Stwds	5
#Cooperatives	195
#Uncooperatives	50
Total Heads of Households	250
Chance to be Env Stwd	50%
Chance to be Cooptv	25%
Chance to be Uncooptv	5%
Dump?	on
Dump once per	7 days
Dump trash/person	4 lbs
Clean?	on
Clean once per	30 days
Clean trash/person	40 lbs

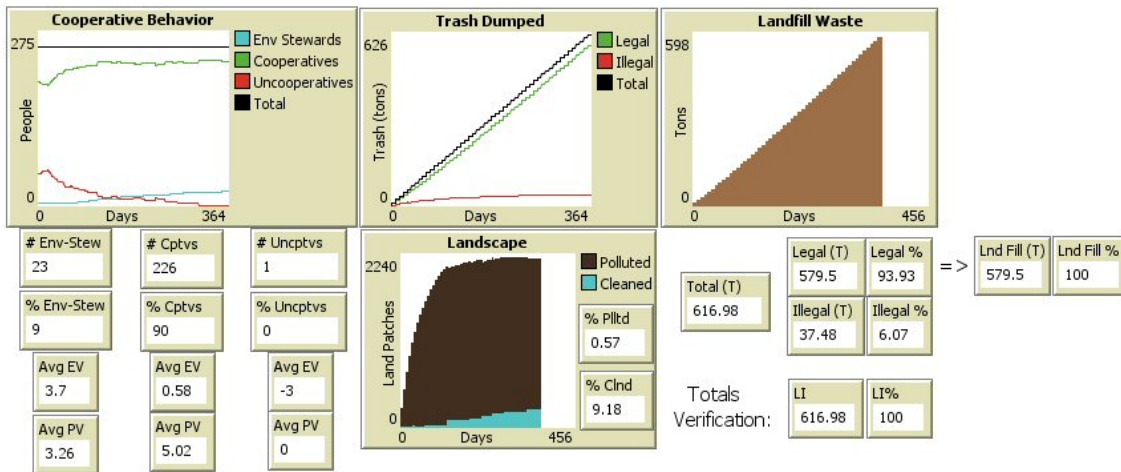


Fig. 4.6 TCL-HEI Tier-I (v9.0) Discovery Trial #1C @ 365

Discovery Trial #1C (Fig. 4.6) resulted in most of the *uncooperatives* changing their value orientation to a positive perspective and with an increase in *environmental stewards* from a start of 5 to 23 within 365 iterations. Illegal trash dropped to 6% compared to 19% in Discovery Trial #1A (Fig. 4.4) with 9% of the polluted landscape getting cleaned up.

In summary, it became very apparent to me that in fact it is possible to explore dynamic relationships between individuals and to learn how these relationships can result in a collective awareness that can bring about sustainable cooperative action and change. In my study the focus was on illegal trash dumping—an issue that was adopted by participants in the local community and explored through photovoice, artvoice and the CACB model. My next task was to step up the complexity of the social-ecological system being modeled with a parameterization around economic variables that I did in a Tier-II version. The aim in doing this was to evaluate how the behavior and action experienced in Tier-I might change under an added layer of positive and negative economic complexity. Due to this new level of complexity, the model in essence became a new

model but I am calling it the same, just with an additional layer of economic complexity at Tier-II.

MODEL 2 TIER-II: *TAKING CARE OF THE LAND – HUMAN-ENVIRONMENT INTERACTIONS: ECONOMICS, RECYCLING, AND CLEAN-ENERGY*

Q3 – What might a theoretical *Regional Cooperative Clean-Energy Economy* (RCCEE) look like through the lens of the TCL-HEI agent-based model depicting a clean-tech waste-to-fuels process as a sustainable entrepreneurial solution to create energy and jobs, and what are some likely positive and negative consequences for the regional environment and economy?

Tier-II of TCL-HEI was created to address the third research question. This is an entirely hypothetical scenario within the context of my field site but with real possibilities as the clean-technology exists to create an environmentally friendly waste-to-fuels processing plant around that a *regional cooperative clean-energy economy* might begin to emerge. In its theoretical state, such an economy could be based around a cooperative framework where all people would have the opportunity to participate just as many do today in thousands of business co-ops across the country. Entrepreneurship to the Navajo is not a novel concept. As was explored in Phase-I many of the participants may not have been aware of the term *entrepreneur* but once the concept was explained they understood it and entrepreneurial examples were discussed. The literature also points to the growing trend regarding indigenous entrepreneurship; for example Hindle et al. (2005) in their study with indigenous populations in Canada have found a wide interest where “participation in the global economy through entrepreneurship and business development is widely accepted as the key to economy building and nation ‘re-building’ ” (Hindle, et

al., 2005, p. 1). In quoting Bebbington (1993) Hindle, et al. (2005, p. 5) point out that some Indigenous are negotiating an economic integration with main-stream society to “pursue local and grassroots control ... over the economic and social relationships that traditionally have contributed to the transfer of income and value from the locality to other places and social groups”. Furthermore, the idea of seeking sustainable entrepreneurship as a mechanism to mitigating environmental degradation is also not novel. In the world of business, sustainability implies profit optimization over the long-term to remain in business. In ecology, a sustainable ecosystem is one that can be “maintained over an extended period of time based on current conditions and practices” (Levin, 2009, p. 791). Therefore, I would conclude that in a social-ecological system these two must be in balance for true sustainability to have a chance. In their article on sustainable entrepreneurship, Dean and McMullen (2007, p. 50) draw out this point:

Environmental economics concludes that environmental degradation results from the failure of markets, whereas the entrepreneurship literature argues that opportunities are inherent in market failure. A synthesis of these literatures suggests that environmentally relevant market failures represent opportunities for achieving profitability while simultaneously reducing environmentally degrading economic behaviors. It also implies conceptualizations of sustainable and environmental entrepreneurship that detail how entrepreneurs seize the opportunities that are inherent in environmentally relevant market failures.

This is precisely the direction that my exploration with the participants in Houck has taken from its inception with Phase-I in identifying a community problem with illegal trash dumping out of a concern for the environment and that inherently goes against traditional Navajo beliefs and respect for Mother Earth. The culmination of the exploration in Phase-III is to open up possibilities for a sustainable entrepreneurial solution that addresses a balance between the environment and economic pursuits.

A theoretical conceptual model of the high-level interactions of a possible Regional Cooperative Clean-Energy Economy (RCCEE) might look something as depicted in Fig. 4.7. The RCCEE model depicts a theoretical regional community that has

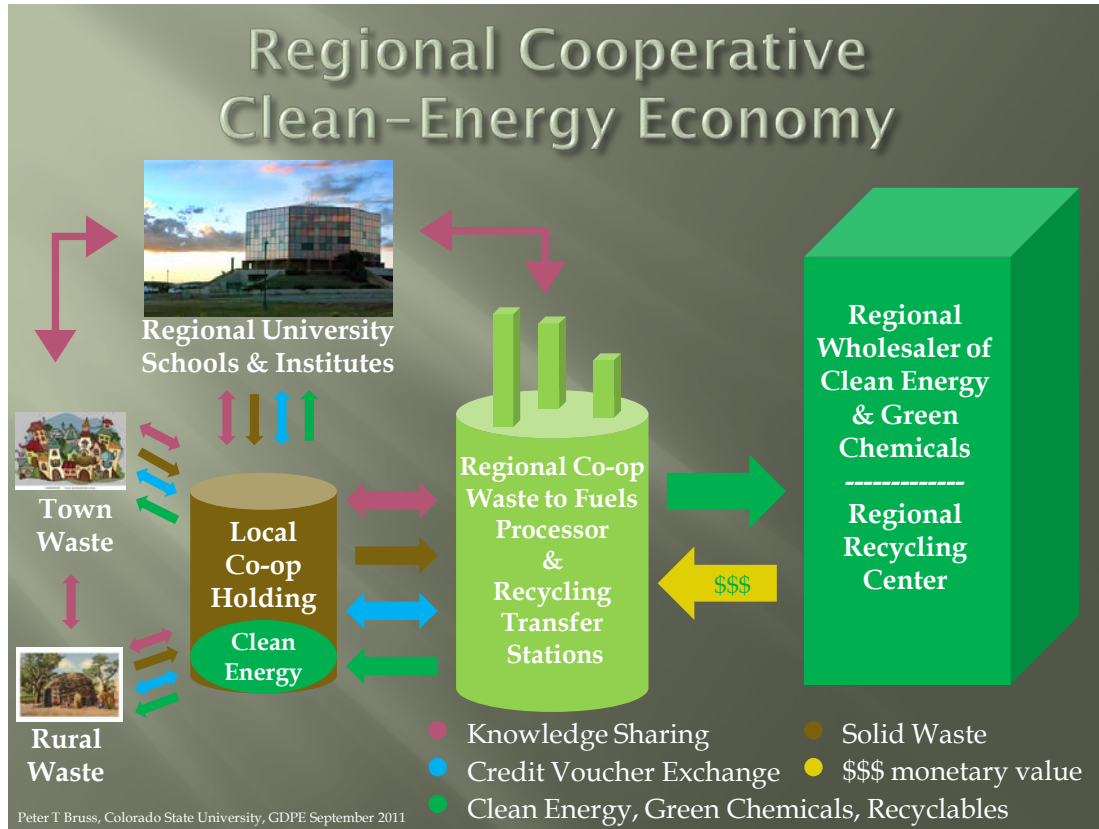


Fig. 4.7 Regional Cooperative Clean-Energy Economy

adopted a trash recycling and waste-to-fuels system. It first begins with consultation, reflection and a sharing of information, ideas and knowledge between people and institutions at local and regional levels and this continues through the process. Solid waste from rural and municipal locations (households and institutions) is sent into a regional co-op holding facility where it is sorted for recycling and waste-to-fuels with compostable biomass (not shown) being hauled off for composting. The waste-to-fuels and recyclable trash is given in exchange for a coupon with a nominal value to be set

depending on the end-use value of the waste-to-fuels and recyclable materials. The materials are then sent down stream by the business co-op for processing in exchange for a monetary value and/or clean-energy depending on the business model of the co-op.

The basic premise of this model is to portray a shift in the dynamics of the current structure in place in the Houck area that imposes a disincentive to dump trash legally through the imposition of a tipping fee—a standard practice across the country at most trash collection points and transfer stations. Overall, the objective of a tipping fee is to offset the costs of trash handling and disposal to landfills. However, in back-country rural areas, if these costs could be lessened or removed entirely the behavioral dynamics, I am suggesting, might change dramatically, particularly in the rural areas of Houck where there are no municipal trash collection services and distances for hauling private trash are great. These distances combined with rising fuel costs and a tipping fee for trash disposal are key motivators driving the behavior of illegal trash dumping as revealed during community gathering discussions during Phase-II.

Under the aegis of the Navajo Nation and the North West New Mexico regional Solid Waste Authority Joint Powers Act of June 2000, the Navajo Nation Long Range Comprehensive Solid Waste Management Plan was published by the subcontractor, Jacobson Helgoth Consultants (Helgoth, 2000). This was a cost study to shut down illegal landfill sites and to evaluate the cost of exporting trash off the Navajo Nation to legal landfill sites. The study revealed that the Navajo Nation is spending an estimated \$72 million annually to haul trash off the Navajo Nation to legal EPA-permitted landfill sites. If such funds could be diverted into the building of a waste-to-fuels processing facility and restructuring solid waste transportation routes and recycling centers, the theoretical

model aims to show that the overall impact could be net-positive in terms of landfill and transport fuel cost-savings, second-generation clean fuel creation and environmental protection through mitigation of illegal dumping and excessive landfill usage.

In brief, clean-technology exists to convert post-recycled municipal solid waste (MSW) into second-generation or cellulosic biofuels. A second-generation fuel is one that is not produced from starch or sugar crops, thus avoiding unintended economic or environmental consequences. Further, there are clean-tech processes already in operation that are net-energy positive, meaning the total energy output exceeds any energy input requirement and the process itself is a clean-process with minimal polluting side effects to the environment. Some advanced clean-tech processes use a low heat (thermal) catalytic chemical conversion process of turning MSW into methanol and ethanol.

Finding a way to create a sustainable entrepreneurial system that incentivizes legal trash dumping is the focus of this section using the ABM *Taking Care of the Land – Human Environment Interactions*: Tier-II. If it can be shown theoretically that such a cooperative system is feasible in a relatively small and rural Chapter like Houck then perhaps the opportunities are even greater in more populated centers on the Navajo Nation. Further, if there is sufficient interest in exploring this by other Chapters then perhaps there is a chance that the Navajo collectively can change their social reality that is impacting the natural environment into a reality that tackles the issue of illegal trash dumping as a whole on the Navajo Nation. In so doing, they might emerge as leaders for others to follow across the country where similar problems persist. Perhaps this could be a future research topic for a promising young Navajo student/researcher emerging from the Diné College on the Navajo Nation or the University of New Mexico Gallup campus.

In order to run this in the Tier-II model, an assumption is made that such a waste-to-fuels facility is already accessible and that the waste stream coming out of Houck is in part feeding the clean-energy process as well as a recycling initiative. Aspects to both of these entrepreneurial opportunities could be formed through a cooperative business venture at the Chapter level to tie into a larger business co-op network at the Navajo Nation level. In doing so, the overall expected impact would be a sustainable entrepreneurial solution that would create clean-energy, jobs, reduce illegal trash dumping, mitigate landfill use and lessen overall environmental degradation.

In keeping with the overall theme of my research, the TCL-HEI Tier-II agent-based model is a first attempt to begin looking at some of the complex dynamics involved in creating such a *Regional Cooperative Clean-Energy Economy* starting at the Houck Chapter level. The initial focus being addressed here at the Tier-II level is how will certain key economic variables impact behavior such as the cost of dumping that would include the cost of tipping fees and fuel for a person looking to dump legally or just fuel cost for someone looking to dump illegally. The question then becomes at what point does it become economically attractive for an *uncooperative* to dump legally if there are incentives built into a business cooperative model for the *uncooperative* to do so.

Tier-II: Overview, Design and Detail

As Tier-II is an overlay to Tier-I in the TCL-HEI model, both the code and the ODD description will be enhancements to what was already presented above for Tier-I. In this section, I will simply present the additional ODD descriptive pertaining to Tier-II and not reiterate what has already been stated above for the ODD-Tier-I.

ODD-Entities, State Variables, and Scales:

Tier-II adds the entity illegal dumpsites that are fixed locations to the landscape and used as reference points for determining distance that is then used in the calculation for the cost of dumping trash for uncooperatives. The reality on the ground is that there are multiple illegal trash sites including random dumping along the roads and it would be virtually impossible to know who goes to which site or where a random dump might be made as this is not information to which anyone would readily admit. However, there are a few larger sites and I chose to use these as distance-calculation reference points designated with black triangles (Fig. 4.8). The exact locations of these are not relevant as these could be cleaned up and new ones created making these sites irrelevant. What is important here is having a fixed reference point to which all *uncooperatives* can refer so that a comparative analysis can be made. The code asks each *uncooperative* to choose the illegal dumpsite that is closest to itself assuming this would be a logical economic decision. This type of decision making corresponds to rational expectations theory in economics that essentially states that rational individuals will use all available and relevant information to make decisions that are marginally beneficial to their own economic wellbeing (Pearce, 1983).

ODD-Process Overview and Scheduling:

Tier-II does not add any new dynamic process to the model but enhances the dump and clean routine significantly tying them in with economic variables discussed below.

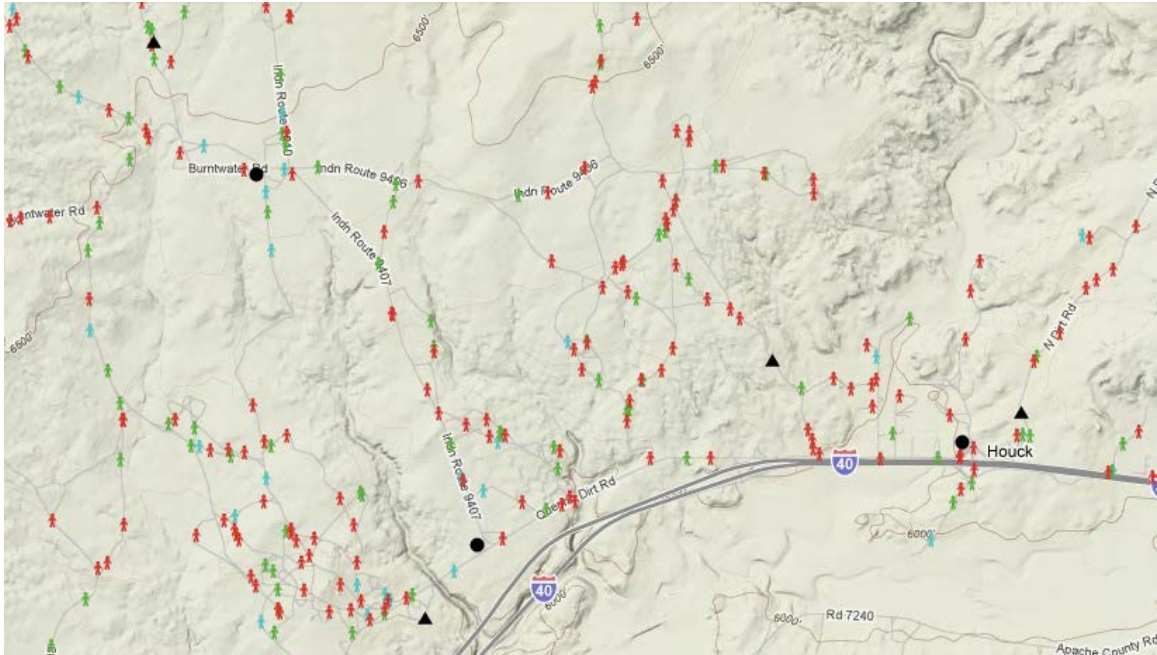


Fig. 4.8 ABM TCL-HEI: Illegal Dump Sites (▲) and Places (●)

ODD-Design Concepts:

Outcome and Expectation: Just as with Tier-I, the Tier-II model objective and outcome is an emergent sustainable behavior and action towards environmental cleanup. The additional feature in Tier-II comes with the values selection of various economic variables. The outcomes of the model are very much dependent on the selection of any one of these variables from both Tier-I and Tier-II. The additional Tier-II variables include fuel cost and miles per gallon efficiency which influence economic-based decisions such as driving; the variable values selection of trash collection-point tipping fees; the variable values selection of recyclables that include %recyclables available, recyclable \$ value and recycle \$ coupons that co-op members would receive in exchange for dumping trash that goes towards that process; and, the variable value selection of

clean-energy (ce) processing that include ce \$ value and ce \$ coupons that co-op members would receive in exchange for dumping trash that goes towards that process.

Objectives, Learning, Prediction: Tier-II ties a person's environmental value (EV) to the prevailing economic scenario created that in part drives decision making. The EV is changed either up or down based on an order of magnitude linked to that person's wealth index, a net\$ calculation. If the prevailing economics dictate that the person is losing money by dumping then the EV is impacted negatively. If they are making money then the EV is raised accordingly. The distinction is that while an *uncooperative* is already making decisions based on economics alone without regard for the environment, the *environmental stewards* and *cooperatives* have not been. The nature of an *environmental steward* and a *cooperative* is to take care of the environment or at least not degrade the environment in the case of the *cooperative*. That is what defines them and they will continue to do so even in tough economic times until it becomes too tough economically that they are forced into taking a decision to stop their pro-environment behavior. The gradual eroding of their EV over time due to a poor economic climate will eventually result in their behavior pattern matching that of a lower EV type, in which case their person type will adapt into that of the lower order, e.g., the *environmental steward* will become the *cooperative* and the *cooperative* will become the *uncooperative*. So long as the difficult economic conditions persist, this transitioning will continue until the entire population has evolved into *uncooperatives*. The rational is that economics plays a very powerful role in our decision-making that in turn impacts the environment. However, in building a *Regional Cooperative Clean-Energy Economy* the model allows the reverse also to be true. Although the overall prevailing economic conditions may be

poor with high fuel costs and Chapter's having to charge at least nominal tipping fees to cover the cost of hauling away deposited trash, the fact remains that trash is still being accumulated at a rate of 4 lbs per person a day and needs to go somewhere. Therefore, why not capitalize on this fact and turn the negative into a positive. Through collective action and awareness the local population can arise to form a business cooperative that enables for a collective process of recycling and clean-energy. The potential wealth created from this behavior of cooperation will begin to offset the economic negatives and further encourage participation in the program. As this happens a person's EV begins to grow, also in proportion to its own wealth index (net\$) and the population can literally transform itself out of poverty and environmental degradation into a situation of growing prosperity, wealth accumulation and environmental sustainability.

Sensing: Tier-II calls for all people to sense and react to the global economic environment when switched on. It enables the sensing of changes in economic parameters and allows for a response accordingly.

Interaction: Tier-II brings no new change to interaction other than a heightened awareness of change through the EV as discussed above.

Stochasticity: Tier-II's application of an economic layer does not alter the already inherent stochasticity introduced in Tier-I. Although certain economic variables such as the recycle and clean-energy coupons are percentage based, they are not probabilistic.

Observation: Tier-II introduces some new features to the model. The variable sliders cover tipping fees, truck fuel, miles per gallon efficiency, what percentage of trash gets recycled, the dollar value for recycled trash, what percentage recycle-coupon is

distributed back to co-op members, the market value for clean-energy (waste-to-fuels ethanol in this case), and what percentage clean-energy coupon is distributed back to co-op members. New monitors include an addition to the solid waste stream tracking with the addition of recycle and waste-to fuels monitors. There is also a new batch of wealth related monitors including a row for aggregate net\$ and a row for these net\$ on a per capita basis. These are on a per tick or transaction basis and are not cumulative. The reason for this is that each new transaction calls for a reevaluation of the underlying economics to decision making. The monitor for Co-op\$ tracks wealth of the business co-op. The key is to find a sustainable and just balance between Co-op\$ accumulation and what can best drive environmental stewardship along with community prosperity. Combined, this *collaborative adaptive capacity building* approach is viewed as being able to lead towards a more sustainable and resilient social-ecological system.

ODD-Sub-models and Switches:

Tier-II introduces the economic? switch to be able to evaluate the model in or out of the economic mode.

ODD-Simplifying Assumptions:

A significant assumption implicit in the model is that a clean-energy processing facility is operational and receives solid waste from Houck at a fair market value. The recyclable trash is monitored separately based on estimated averages by type. However, for the sake of simplicity, the \$ value for the recyclables is based on a lump sum basis.

Discovery

The above section introduced what a *Regional Cooperative Clean-Energy Economy* might begin to look like. This section will further explore this theme looking at results of some applied economic scenarios using Tier-II of TCL-HEI. My approach was to run fairly conservative but likely economic scenarios using the same random seeds and variable settings for the Tier-I baseline trials. However, because new features have been added to the model, the model is in essence a new model even if just slightly. For example, even though I use the same random seed, say for example the one I used for Tier-I Trial#1, and even though I would not deploy any of the economic variables set up for Tier-II, i.e., keeping it the same as if in Tier-I, the results would still come out slightly different. This can be seen even when comparing the initial setup patterns. One reason that I could account for this being the case is due to the marginal differences between Tier-I and Tier-II such as with new places like trash sites. In Tier-II, I added four more agents and even though economics is switched off, there is still new code that is read such as “ifelse economics?” to determine to skip the economics routine. Features as simple as this are enough to marginally change the outcomes between the Tier-I and Tier-II trials. Notwithstanding these differences, I chose to go with the initial variable settings used in the Tier-I Discovery Trial #1A but I do not make a side-by-side comparison. Instead, I build on the results as if it were a new baseline. The look of the new interface for TCL-HEI Tier-I & II (v9.2) is shown in Fig. 4.9.

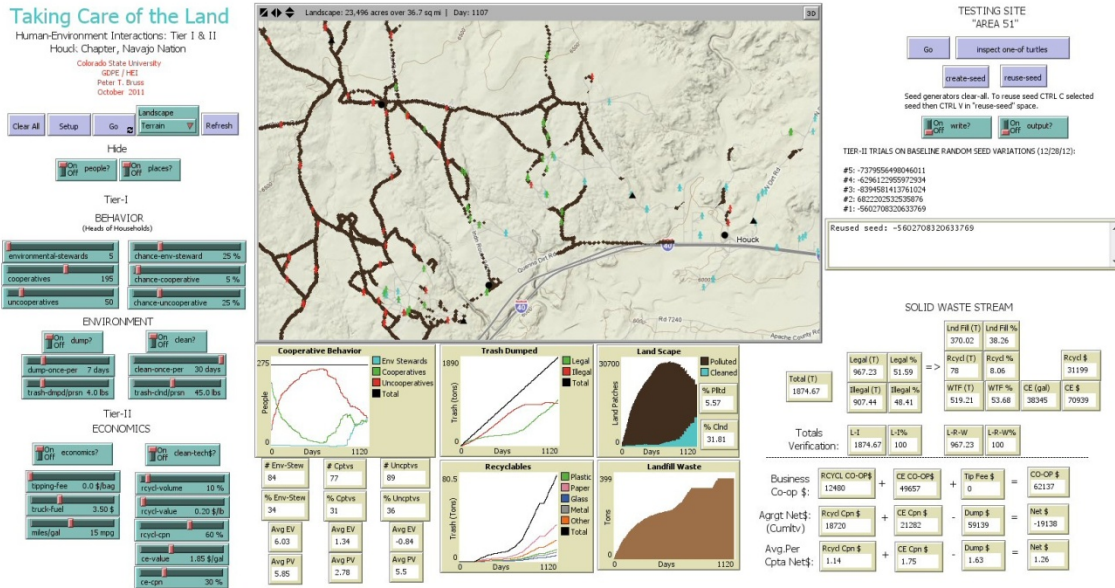


Fig. 4.9 TCL-HEI Tier-I & II (v9.2) Interface

Results for Tier-II Discovery Trial #1A with no economics are shown in Fig. 4.10 and Fig. 4.11 using the following variable settings.

Tier-II Discovery Trial #1A (economics? off)

Random seed	-5602708320633769
#Env Stwds	5
#Cooperatives	195
#Uncooperatives	50
Total Heads of Households	250
Chance to be Env Stwd	25%
Chance to be Coopty	5%
Chance to be Uncoopty	25%
Dump?	on
Dump once per	7 days
Dump trash/person	4 lbs
Clean?	on
Clean once per	30 days
Clean trash/person	20 lbs
Economics?	off
Tipping fee \$/bag	\$0.00
Truck Fuel \$/gal	\$0.00
Miles/gal	0
Clean-tech\$?	off
Volume recycled	0%
\$/lb value for recycled	\$0.0

Recycle coupon back (% of Co-op Recycle\$)	0%
Clean-energy market value (\$/gal)	\$0.0
Clean-energy coupon back (% of Co-op ce-\$)	0%

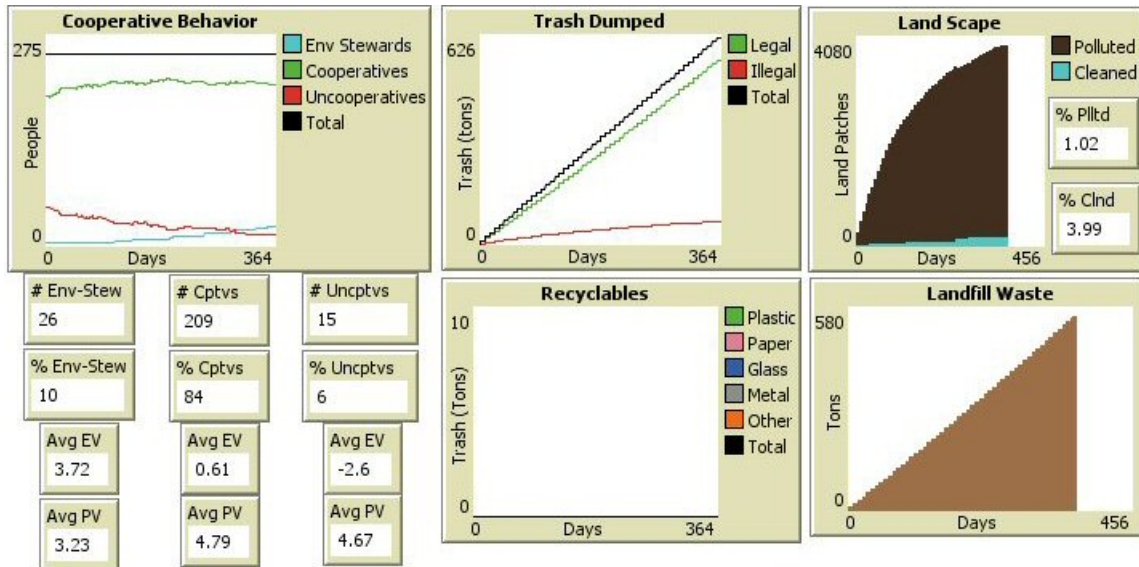


Fig. 4.10 TCL-HEI Tier-II (v9.2) Discovery Trial #1A Plots (economics? off)

As seen in a comparison with the Tier-I Discovery Trial #1A (Fig. 4.4) there are sufficient differences despite using the same initial variable settings. However, it is interesting to note that Fig. 4.10 is very similar to the positive incentive scenario Discovery Trial #1C (Fig. 4.6). Out of curiosity I chose to run both models again to verify no mistakes had been made. I came to the conclusion that while there are close similarities in the plot outcomes this is due to the differences in random distribution when using the same seed due to the minor variation in model parameterization and further justifies my reasoning for going with the Tier-II Discovery Trial #1A results as the new baseline for the next discovery runs. However the interpretive story is not all that different. In essence the hypothetical scenario in Fig. 4.10 shows that *cooperatives* continue to dominate the landscape and that over time due to the positive influence of the

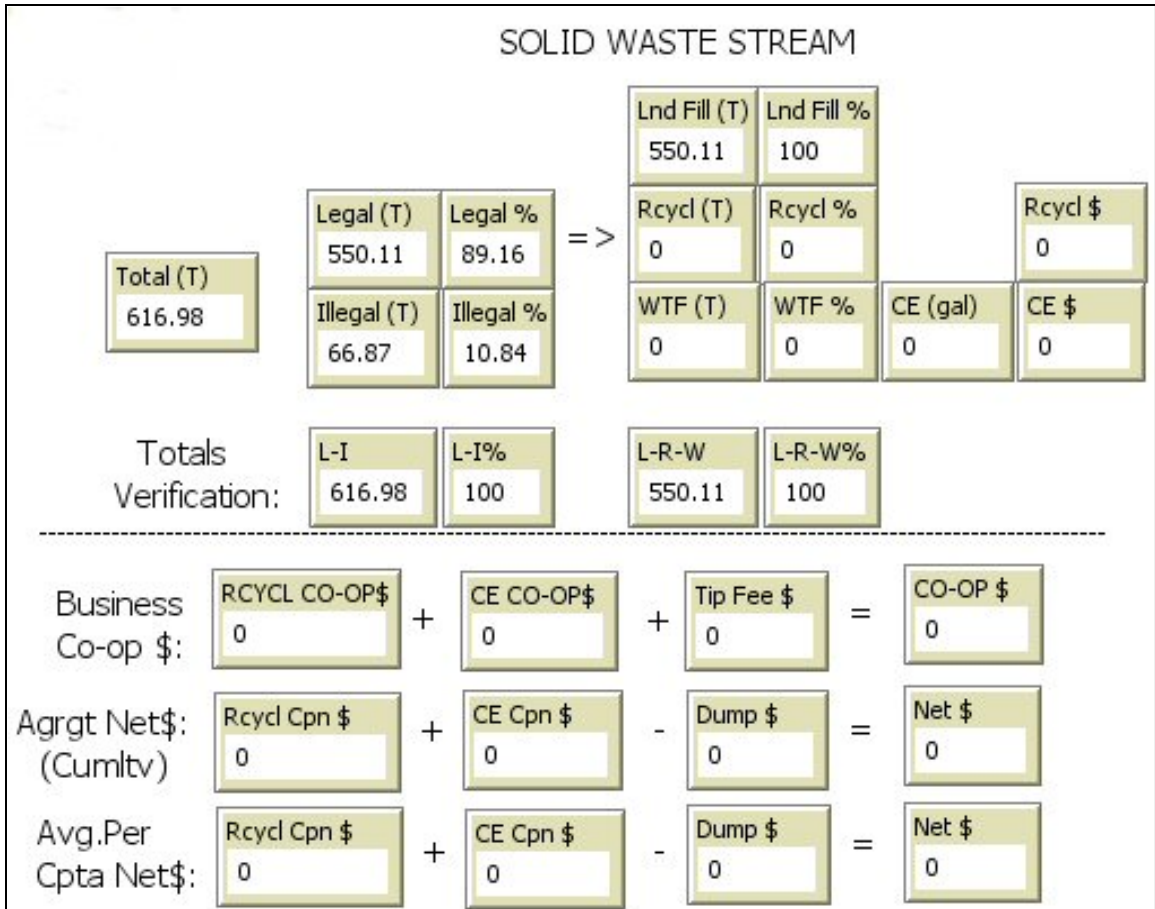


Fig. 4.11 TCL-HEI Tier-II (v9.2) Discovery Trial #1A Data (economics? off)

few *environmental stewards* and the *cooperatives*, the *uncooperative's* behavior gradually changes and some of them adapt to becoming either *cooperatives* or *environmental stewards* and a gradual decline in illegal trash dumping accounting for about 11% of total trash (Fig. 4.11) after 365 iterations. In order to take this a step closer to the social-ecological system on the ground I needed to add a layer of economic complexity so I ran Tier-II Discovery Trial #2A using the same settings as used for Tier-II Discovery Trial #1A except with economics? switched on while keeping clean-tech\$? off as I have not yet introduced any clean-energy recycling program. A change made to the Tier-II code with economics? on as discussed above in the ODD section, is that now

environmental stewards are subject to having their environmental value orientation shifted downward due to forces of negative economics. The Tier-II Discovery Trial #2A settings are as follows.

<u>Tier-II Discovery Trial #2A (economics? on / clean-tech\$? off)</u>	
Random seed	-5602708320633769
#Env Stwds	5
#Cooperatives	195
#Uncooperatives	50
Total Heads of Households	250
Chance to be Env Stwd	25%
Chance to be Cooptv	5%
Chance to be Uncooptv	25%
Dump?	on
Dump once per	7 days
Dump trash/person	4 lbs
Clean?	on
Clean once per	30 days
Clean trash/person	20 lbs
Economics?	on
Tipping fee \$/bag	\$1.00
Truck Fuel \$/gal	\$3.50
Miles/gal	15
Clean-tech\$?	off
Volume recycled	0%
\$/lb value for recycled	\$0.0
Recycle coupon back (% of Co-op Recycle\$)	0%
Clean-energy market value (\$/gal)	\$0.0
Clean-energy coupon back (% of Co-op ce-\$)	0%

In this sceario the tipping fee that is the cost to dump trash at the Houck Chapter collection point is \$1.00 per bag and the Tier-II model makes the assumption that an average size yard bag would weigh about 20lbs. Fuel cost is set at \$3.50 that is not unrealistic during these times as is a 15 mpg setting where most vehicles are trucks and they are driving for long periods of time on dirt roads, often not graded, that lowers fuel efficiency. The results for these settings are shown in Fig. 4.12 and Fig. 4.13.

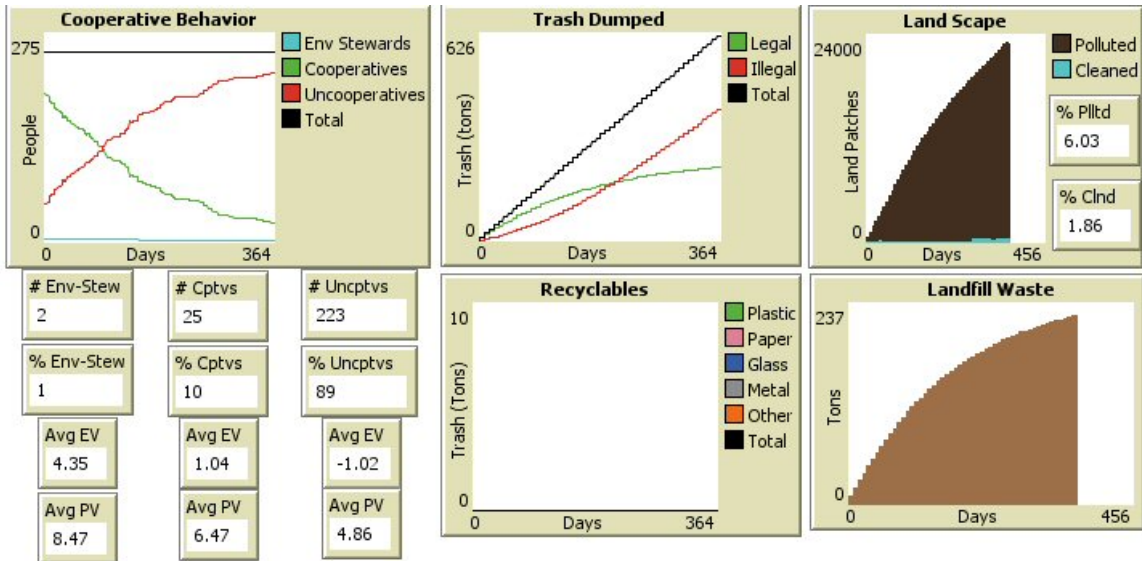


Fig. 4.12 TCL-HEI Tier-II Discovery Trial #2A Plots

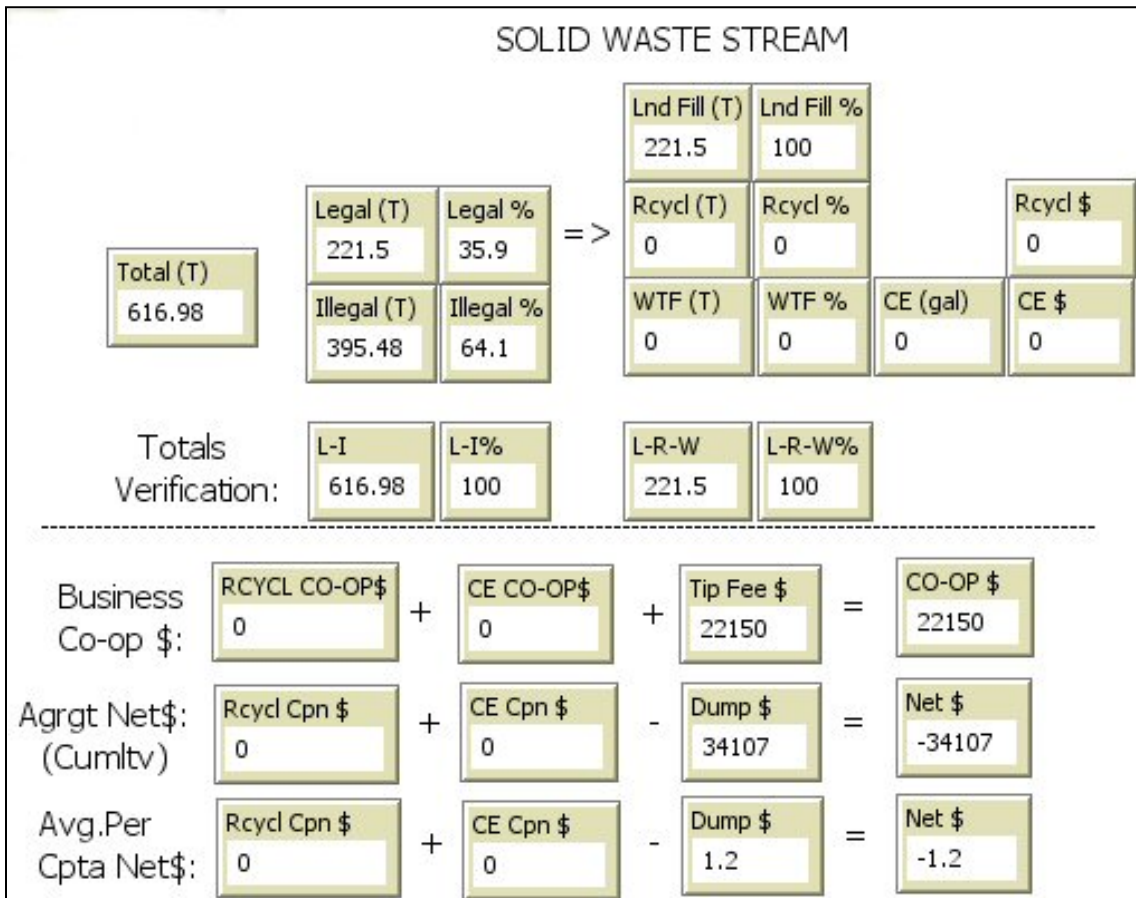


Fig. 4.13 TCL-HEI Tier-II Discovery Trial #2A Data

The results for the Tier-II Discovery Trial #2A (Fig. 4.12 & Fig. 4.13) indicate a significant shift in behavior. The trajectories in behavior relative to each other are key over time. In this Tier-II Discovery Trial #2A, despite attempts on behalf of *environmental stewards* and *cooperatives* to persuade *uncooperatives* to change behavior that resulted in some positive effect as previously seen in Fig. 4.10, the effect is entirely overrun by action driven by the economics of a \$1.00 per 20lb bag tipping fee and a \$3.50 per gallon gas price (Fig. 4.12). The *uncooperatives* quickly surpass the *cooperatives* at around iteration 90, that represents the first global feed back indicating a repositioning of the social-ecological system dynamics. This general resilience theme is discussed below. Then at around iteration 200 there is a cross-over of illegal trash dumping exceeding legal trash dumping resulting in illegal-trash accounting for 64% of total trash after 365 iterations (Fig. 4.13). A new set of data can also be seen in Fig. 4.13, that of aggregate and per capita dump cost. The aggregate net\$ figure (-34,107) tracks aggregate totals while the average per capita net\$ figure (-1.2) is on a transaction basis and is based on the assumption that an individual will take a decision given the economic information for a given transaction and not based on a cumulative history. This assumption may be more appropriate in lower income situations than in higher income situations where savings and the propensities to consume are different due to a wealth factor. This is a notion that correlates to the economic theory known as the income elasticity of demand that is “a measure of the responsiveness of the quantity demanded of any *good* to a change in the level of income of the persons demanding the good” (Pearce, 1983, p. 199). With Tier-II, each agent asks itself where is it cheaper to dump trash, at the collection point or illegally? In all cases the *uncooperative* will dump illegally whenever

it is cheaper to do so because they have a negative value orientation for the environment and if they choose to dump in a legal location it is because it is the most economical option at that time. However the *cooperatives* and *environmental stewards* ask this question but they continue to dump legally even if it is more expensive as they are driven by a positive environmental value orientation that at least dictates they will not degrade the environment. In the case of the *cooperative* this may simply be a moral factor of knowing right from wrong but to the *environmental steward* it is deeper than that with a love for nature. Over time, however, the economic forces continue to erode both their value orientations until they, on an individual basis, reach a tipping point and they give into the overwhelming demands of economic forces to eventually adapt into *uncooperatives* as their values cross the threshold between that of a *cooperative* (+) to that of an *uncooperative* (-).

In this hypothetical scenario, I make the case that at the outset the system was in a relatively desirable state of affairs as seen in Discovery Trial #1A (Fig. 4.10). However, with the introduction of these two economic factors (tipping fees and gas prices) the system shifted into an undesirable state with the threshold being right around 180 iterations when illegal trash dumping became the predominant behavior and the stability landscape within which the system operates continued to morph lower and lower into its new regime basin attractor (see Chapter 5). This is a stylized and exaggerated example of what could be happening on the ground at a more drawn out temporal scale. However, one of the features of modeling is that it allows for changes in spatial and temporal scale to evaluate events in a more compressed manner.

From here I was able to apply the full impact of the model to explore a hypothetical scenario of policy implications to bring about environmental and economic positive change on a more sustainable basis. The premise of the next Discovery Trial#2B was to create a theoretical case study scenario where local officials realize a problem is brewing on the land and so they set out to find a sustainable solution. In this pro forma case scenario one of the local officials mentions she knows a student from Diné College who learned something about a study that was carried out some time back that involved a simulation model called *Taking Care of the Land – Human Environment Interactions* that might be of assistance so they turn to using the TCL-HEI model to generate a theoretical scenario to forecast how long it would take to turn a worsening environmental situation around if they were to apply a steady and regular change using economic tools at their disposal through the creation of a business cooperative that will bring on line a recycle and waste-to-fuels program and to eventually hit coupon targets of 80% for both programs and be sustainable. In the environmental system this would imply a sustained reversal of illegal trash dumping and serious cleanup efforts while in the economic system the business coop must remain solvent with an arbitrarily set revenue floor balance of nothing less than \$2,000. At the end of the run a global scirmish erupts in the Persian Gulf sending oil prices through the roof taking gasoline to \$7.00 / gal. but also ethanol rises by the same factor— is the program sustainable and is the social-ecological system resilient? The results of this theoretical exploration are shared below in the Discussion. The initial and subsequent variable settings for Discovery Trial #2B are as follows.

Tier-II Discovery Trial #2B (economics? on & clean-tech\$? on)

Random seed -5602708320633769

@ Start – business as usual

#Env Stwds	5
#Cooperatives	195
#Uncooperatives	50
Total Heads of Households	250
Chance to be Env Stwd	25%
Chance to be Cooptv	5%
Chance to be Uncooptv	25%
Dump?	on
Dump once per	7 days
Dump trash/person	4 lbs
Clean?	on
Clean once per	30 days
Clean trash/person	20 lbs
Economics?	on
Tipping fee \$/bag	\$1.00
Truck Fuel \$/gal	\$3.50
Miles/gal	15
Clean-tech\$?	off

@ 90 – notice marginal decline in tip\$ revenue

@ 180 – recycling startup

Clean trash/person	30 lbs
Tipping fee \$/bag	\$0.50
Clean-tech\$?	on
Volume recycled	10%
\$/lb value for recycled	\$0.20
Recycle coupon back (% of Co-op Recycle\$)	25%
Clean-energy market value (\$/gal)	\$0.0
Clean-energy coupon back (% of Co-op ce-\$)	0%

@ 270

Tipping fee \$/bag	\$0.40
Recycle coupon back (% of Co-op Recycle\$)	30%

@ 360

Tipping fee \$/bag	\$0.30
Recycle coupon back (% of Co-op Recycle\$)	35%

@ 450

Tipping fee \$/bag	\$0.20
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Recycle coupon back (% of Co-op Recycle\$)	40%
<u>@ 540</u>	
Tipping fee \$/bag	\$0.10
Recycle coupon back (% of Co-op Recycle\$)	45%
<u>@ 630</u>	
Tipping fee \$/bag	\$0.00
Recycle coupon back (% of Co-op Recycle\$)	50%
<u>@ 720-waste-to-fuels startup</u>	
Clean trash/person	40 lbs
Recycle coupon back (% of Co-op Recycle\$)	55%
Clean-energy market value (\$/gal)	\$1.85
Clean-energy coupon back (% of Co-op ce-\$)	20%
<u>@ 810</u>	
Clean trash/person	45 lbs
Recycle coupon back (% of Co-op Recycle\$)	60%
Clean-energy coupon back (% of Co-op ce-\$)	30%
<u>@ 900</u>	
Clean trash/person	50 lbs
Recycle coupon back (% of Co-op Recycle\$)	70%
Clean-energy coupon back (% of Co-op ce-\$)	40%
<u>@ 990</u>	
Clean trash/person	55 lbs
Recycle coupon back (% of Co-op Recycle\$)	80%
Clean-energy coupon back (% of Co-op ce-\$)	50%
<u>@ 1080</u>	
Clean trash/person	60 lbs
Clean-energy coupon back (% of Co-op ce-\$)	60%
<u>@ 1170</u>	
Clean trash/person	65 lbs
Clean-energy coupon back (% of Co-op ce-\$)	70%
<u>@ 1260</u>	
Clean trash/person	70 lbs
Clean-energy coupon back (% of Co-op ce-\$)	80%
<u>@ 1350</u>	
Clean trash/person	80 lbs
Clean-energy coupon back (% of Co-op ce-\$)	80%

@ 1440 – Global shock to oil

Truck Fuel \$/gal	\$7.00
Clean-energy market value (\$/gal)	\$3.70

Dumping once per seven days is within national norms. Four pounds of trash dumped per person each day is below the national average of 4.3lbs and given lower income levels in the Houck Chapter it is reasonable to assume there is less consumption than the national average. Further, this is below an extrapolated average of 4.73lbs per person on the Navajo Nation taken from the engineering study by Helgoth (2000) for various communities around the Navajo Nation. Cleaning 20lbs of trash once per month is purely arbitrary to establish a cleaning routine. Observations during my fieldwork were that the Navajo who were environmentally conscious would clean trash during organized cleanup projects and usually in the summer months. The tipping fee is the actual fee per bag but the use of a 20lb bag is an estimate on my part with the assumption that a larger yard bag would be used to get the most out of the \$1 fee. The price of \$3.50 for fuel and 15 miles per gallon is reasonable given market prices and rough backcountry dirt roads. The average volume of recyclables that come off of municipal solid waste is about 10% (Helgoth, 2000). To simplify the model I chose to run recyclables as a lump value set at \$0.20 per pound payback for all recyclables in this trial run. Lumping recyclables like this is not realistic but was much simpler. Any future business cooperative would of course be separating out the recyclables into the key types such as paper, plastics, glass, woods, metals, compost etc. and selling the accumulated volumes off to the highest bidder at market rates. The percentage coupon back to members for clean-energy and recycling is adjustable but actual calculations might be on a per weight basis of trash by type brought in. The recycle and clean-energy coupons are adjusted incrementally as

economic success improves with the program and represent a sharing of wealth by the Cooperative business with its members. Likewise, as economic success improves and word spreads there is likelihood to be an increase in activity to clean up the environment so trashed cleaned is increased incrementally. A further indicator of a successful program that generates further positive feedback to the system is the ability to eliminate tipping fees in a sustainable way that further incentivises legal trash dumping and enhances sustainability of the program. The clean-tech dollars generated in the model are somewhat generous as they represent a full return on the solid waste put forward when in reality a processor would retain a portion of the value to cover costs, overheads and turn a profit. The clean-energy value of \$1.85 is an approximate market value for ethanol.

The results for the Discovery Trial #2B in plot and table format are shared in a pro forma case study format in the next section.

DISCUSSION

Chaper 4 was devoted to addressing the development and results of the agent-based model *Taking Care of the Land – Human Environemtn Interactions*. To arrive at the final result my path first took the course of developing a Tier-I version of the model that looked primarily at Cooperative Behavior resulting from consultations. Using Tier-I as a foundation I was able to add on a layer of complexity with a Tier-II that invovled certain economic fundamentals relevant to the social-ecological system I was focussing in on. These were transportation fuel costs and tipping fees for legal trash dumping. The final results give an indication of how powerful economic incentives can be in shifting behavior and awareness not only at the individual level but collectively.

With the exception of the hypothetical recycle waste-to-fuels program, this could well be representative of the social-ecological system today in the Houck Chapter where tipping fees and rising fuel costs in a poor economic environment are driving increased illegal-trash dumping behavior that is a known and recognized phenomena across the Navajo Nation. Policy makers and Officials who take decisions might consider the implications of what the model is predicting because if such a scenario were to play itself out over the long term and left unchecked, the outlook for the environment and related public health issues are likely to be exacerbated. In the spirit of photovoice I will discuss the results from Discovery Trial #2B in a narrative format using the hypothetical pro forma case study introduced above.

A HYPOTHETICAL PRO-FORMA CASE STUDY

It was no longer business as usual as local Chapter officials began to notice diminishing tipping fee revenue that they had become accustomed to. This helped cover many of the overheads including the cost of hauling off trash to the landfills. Having heard about a local Navajo who had taken part in a study some time back and who now had a reputation of being well acquainted with the study they decided to call this person in to run a simulation model with that she was familiar. Their goal was to see if the model could determine if the implementation of a recycle and waste-to-fuels program they recently heard about from other Chapters would be beneficial.

After running the model they could see their assumptions about diminishing tipping fee revenues was corroborated (Fig. 4.14) placing them right about where they were, mid-

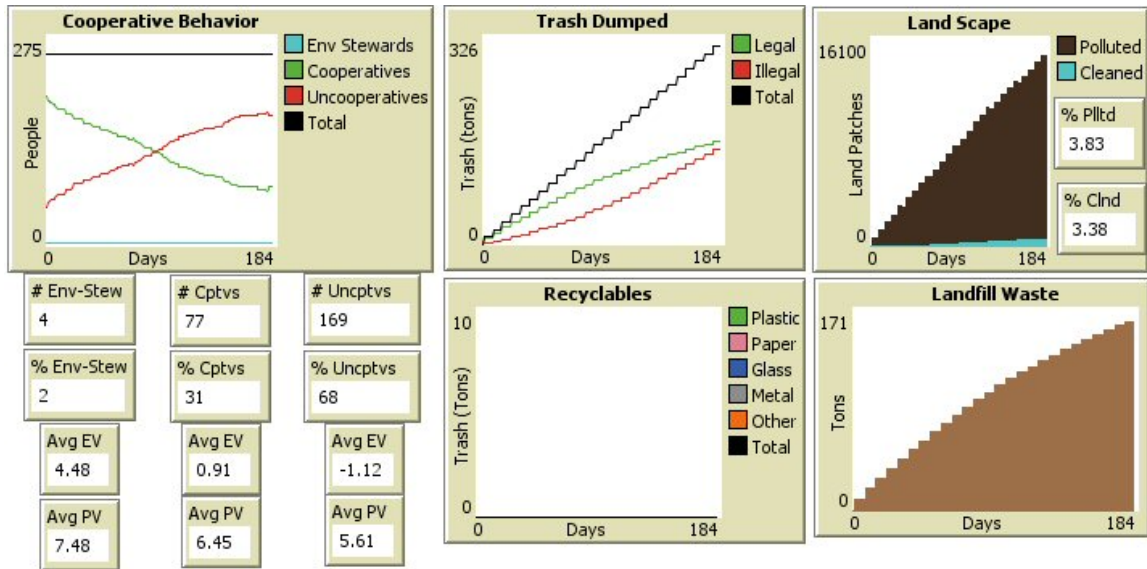


Fig. 4.14 TCL-HEI Tier-II Discovery Trial #2B Plots @ 180

year or about 180 iterations in the model. In evaluating the results of their study they could see that *uncooperatives* were on the rise and *cooperatives* were diminishing and their respective behaviors were having a negative impact on the tipping fee revenue stream as less and less legal trash was being brought into the trash collection point. At the same time they deduced that this must be impacting the local environment in a negative way through illegal trash dumping that was at 48% of total trash and rising (Fig. 4.15) assuming people were not hauling their trash to some other collection point with lower or no tipping fees. As a result of a collaborative community exploration using photovoice and artvoice they were able to determine that in fact illegal trash dumping was on the rise. These two linked issues (declining tipping fee revenue and rising illegal trash dumping) needed to be addressed and quickly. A plan was drawn up to evaluate the economics behind a recycle and waste-to-fuels program with a goal towards achieving both environmental and economic sustainability and they got to work on it.

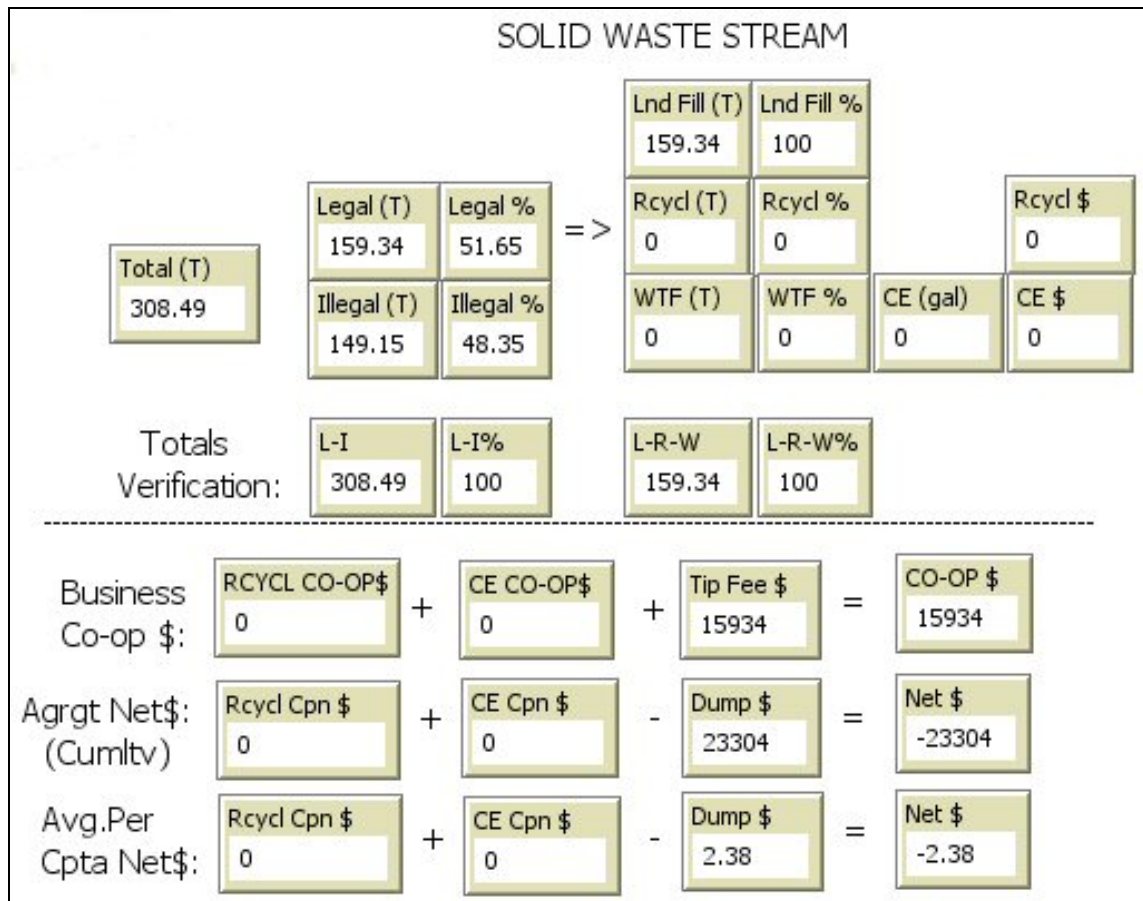


Fig. 4.15 TCL-HEI Tier-II Discovery Trial #2B Data @ 180

Through the development of a business cooperative the recycle program was launched immediately as that was something they had the capacity to organize and implement while the waste-to-fuels program was still under development at a location outside their Chapter and out of their control but soon to come on line. They embarked on their plan with monitoring set quarterly or every 3 months (90 iterations). Their thought was that if they took a steady conservative approach to this they might just make it work and so they agreed that at the end of each 90 day period they would incrementally adjust their program and thus gradually drive the system towards positive change.

Just 3 months (270 iterations) after the launch of the recycle program they could see they were in serious trouble and that it was good they started when they did but was it soon enough? They could see (Fig. 4.16 and Fig. 4.17) the model projecting what looked to be a very unsustainable and potentially dangerous scenario of illegal trash dumping being as high as 58% of total trash generated even though the recycling program was fully underway and there seemed to be little to stop this trend. They were also monitoring the business cooperative's recycle revenue (1,047) and tipping fee revenue (9,711) that amounted to a total revenue base of (10,758). It seemed the recycle program was helping to offset some of the losses from tipping fee revenue but it remained to be seen when the environmental degradation would end. At least now they were beginning to have some idea what was going on, as very little legal trash was being dumped. The

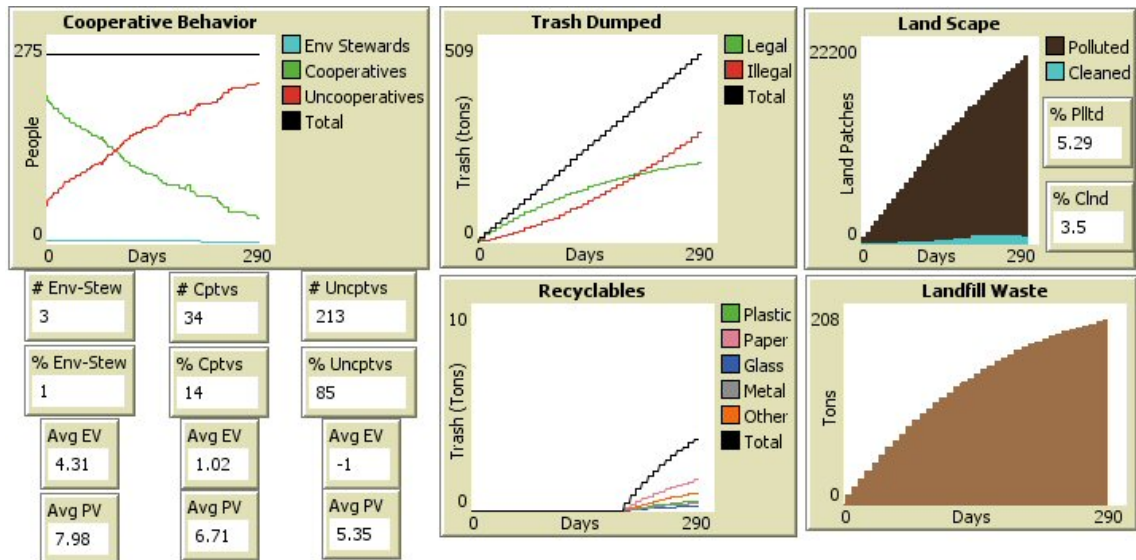


Fig. 4.16 TCL-HEI Tier-II Discovery Trial #2B Plots @ 270

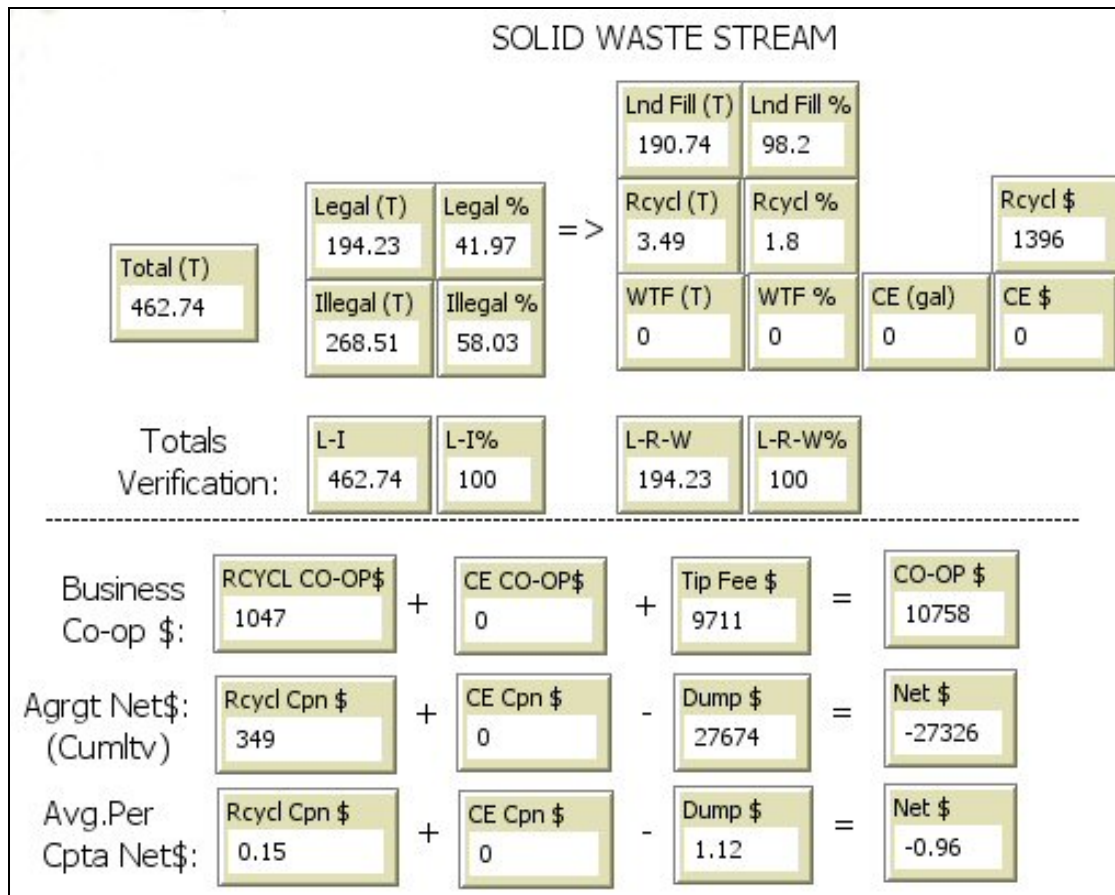


Fig. 4.17 TCL-HEI Tier-II Discovery Trial #2B Data @ 270

model indicated this to be the result of extra spending people had to do on a per capita basis (-.96) and that in difficult economic times people were making choices that it was cheaper to dump the trash illegally than drive all the way down to the collection point and then have to pay the tipping fee and that this outweighed the cost of being caught by authorities assigned to patrol for illegal trash dumping but who were rarely seen in these parts. However, the good news was that since the recycle program kicked in, this per capita net\$ figure had dropped from -2.38 (Fig. 4.15) to -0.96 (Fig. 4.17) in 90 days due to the recycle \$s offsetting the cost to dump trash so it seemed matters might improve if this trend were to be sustained.

When they reevaluated the model again just past a year at 450 iterations, at first glance (Fig. 4.18) the matter seemed to be only worsening as *uncooperatives* had almost

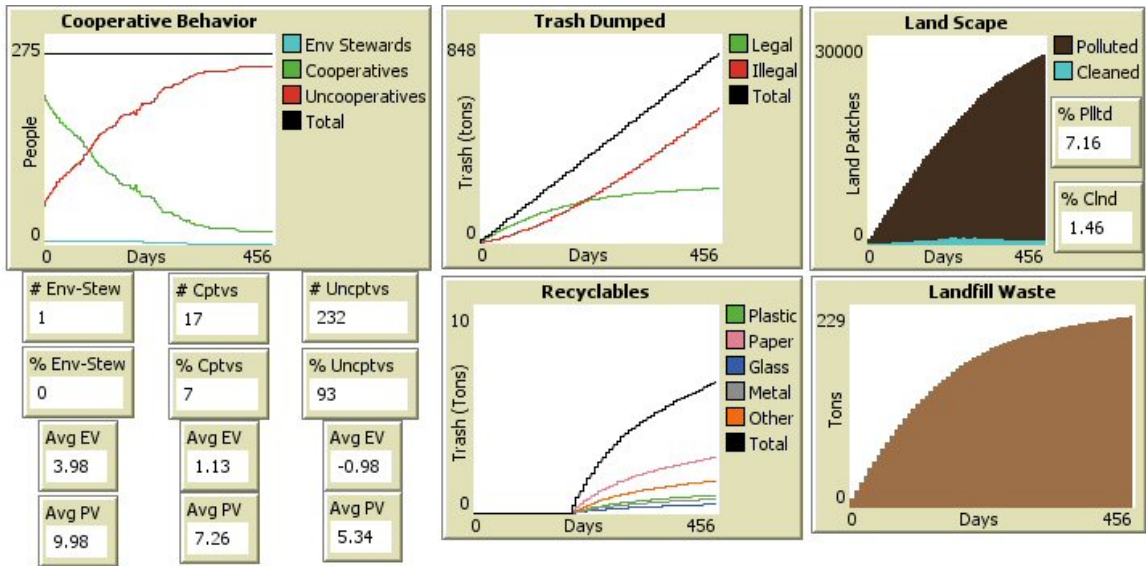


Fig. 4.18 TCL-HEI Tier-II Discovery Trial #2B Plots @ 450

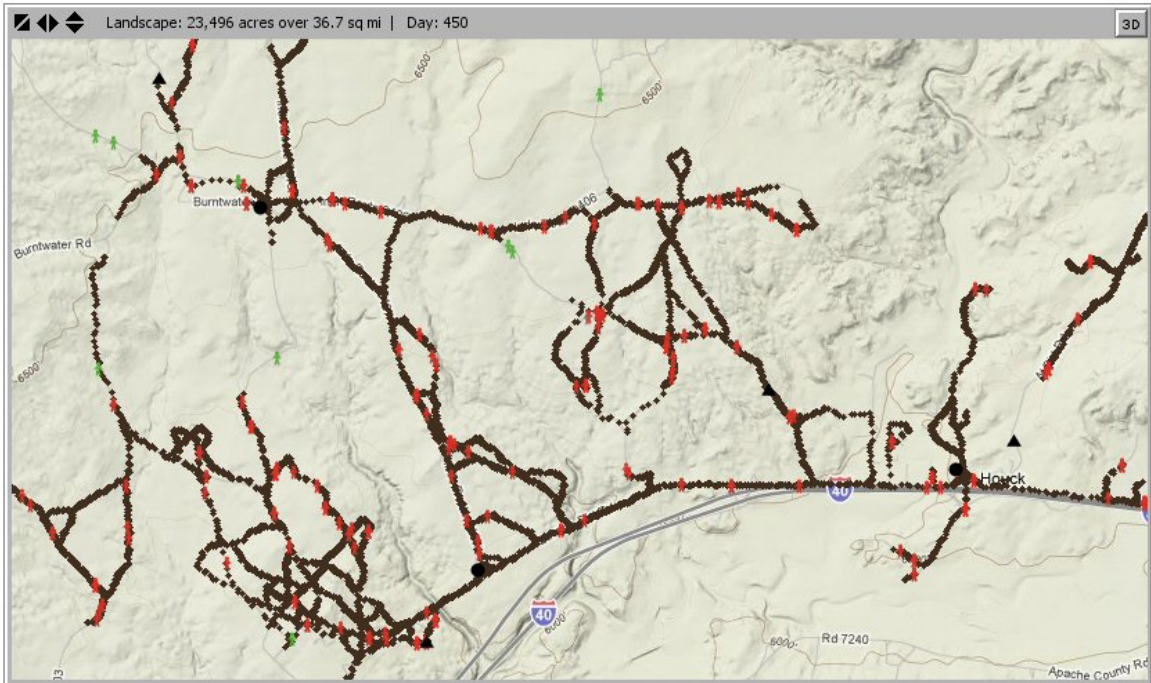


Fig. 4.19 TCL-HEI Tier-II Discovery Trial #2B View @ 450

entirely dominated the system which meant disaster for the environment (Fig. 4.19) with 71% of all trash being dumped illegally (Fig. 4.20). The idea that the situation could get this bad was beyond comprehension but the model was enabling them to see a potentially looming disaster ahead. However, the positive aspect was the recycle program was improving the average per capita dumping cost that was now at a negative \$0.55, an improvement of 41 basis points. Their business co-op\$ balance was dropping but it was still comfortably above their arbitrary solvency floor of \$2,000. They also noticed that some of the trash was being diverted away from landfill as it made its way to recycling and at least this was a good indicator for some marginal environmental improvement.

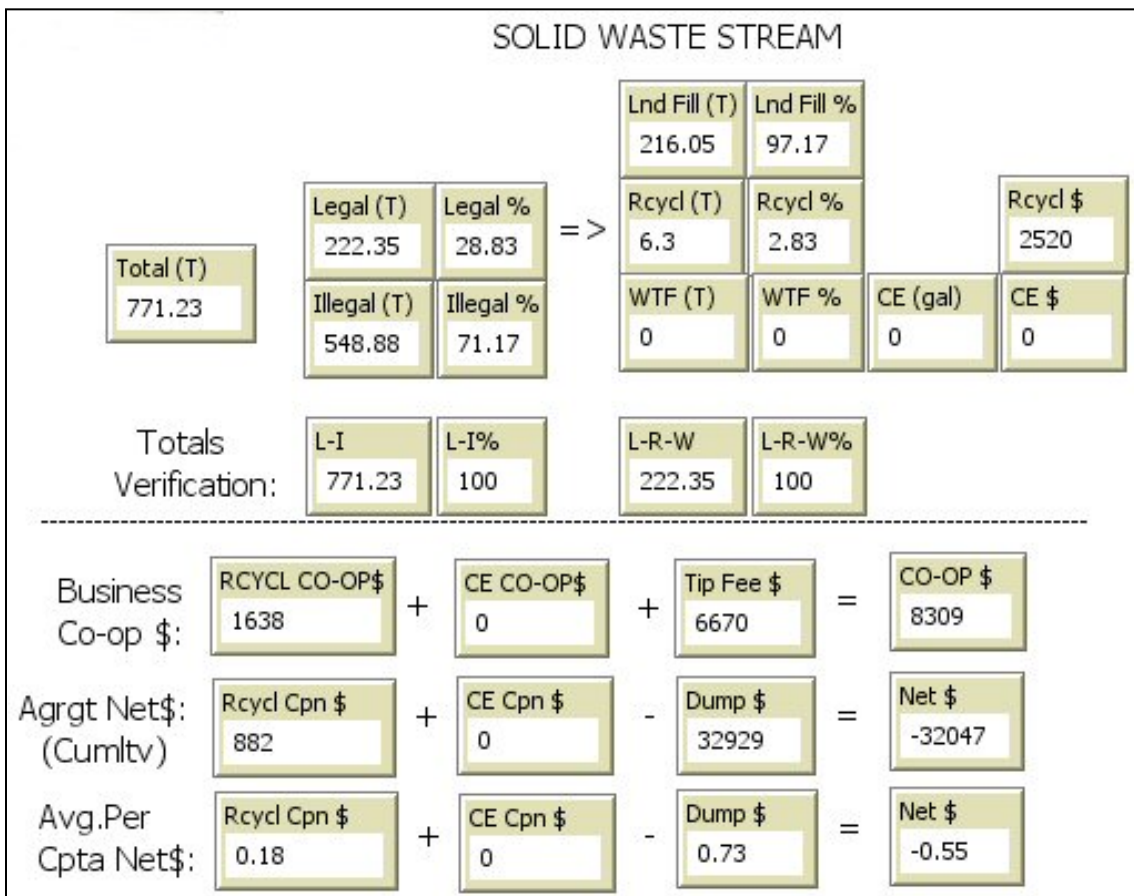


Fig. 4.20 TCL-HEI Tier-II Discovery Trial #2B Data @ 450

By the end of year 2 (720 iterations) they realized for the first time that perhaps they had taken the right decision to act but they still wondered if it was too late? The model had already told them their social-ecological system under study had shifted from a desirable state into an undesirable state at round 180 days when they first started noticing problems (Fig. 4.14). What they were now looking at seemed to be the crest of a terrible scenario as the *uncooperatives* were beginning to lessen and *cooperatives* were on the come back (Fig. 4.21). It seemed the news of the business cooperative recycle coupon program was getting around and that it was having an effect. By now, on average,

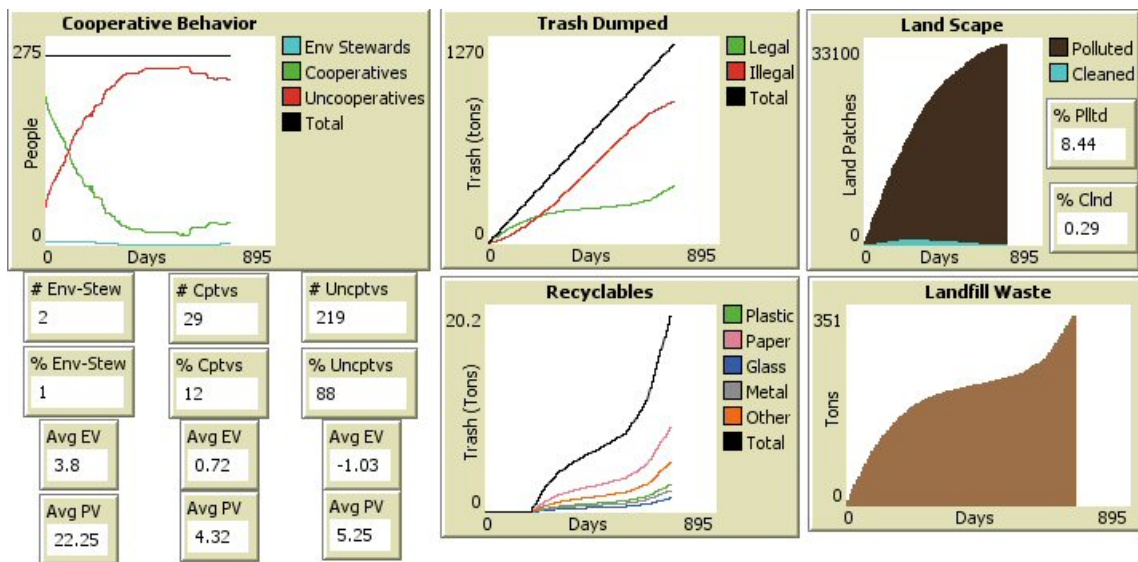


Fig. 4.21 TCL-HEI Tier-II Discovery Trial #2B Plots @ 720

people were just about breaking even with an average per capita net\$ at $-\$0.2$ and no longer losing a lot of money just to dump trash (Fig. 4.22). They also noticed something interesting, that right when *uncooperatives* peaked on the ‘Cooperative Behavior’ plot at around 700 iterations, there was a corresponding trend shift in the ‘Trash Dumped’ plot. Illegal trash dumping was tapering off and legal trash dumping was on the rise that also

corresponded with the visible increase in recyclables in the 'Recyclables' plot. It was also apparent that the 'Landfill Waste' plot was showing an increase in landfill. After some thought, they realized this was a net positive; concluding that although landfill was growing it was due to the increase in *uncooperatives* deciding it was cheaper to dump legally with the new program than to dump illegally and so their behavior was changing.

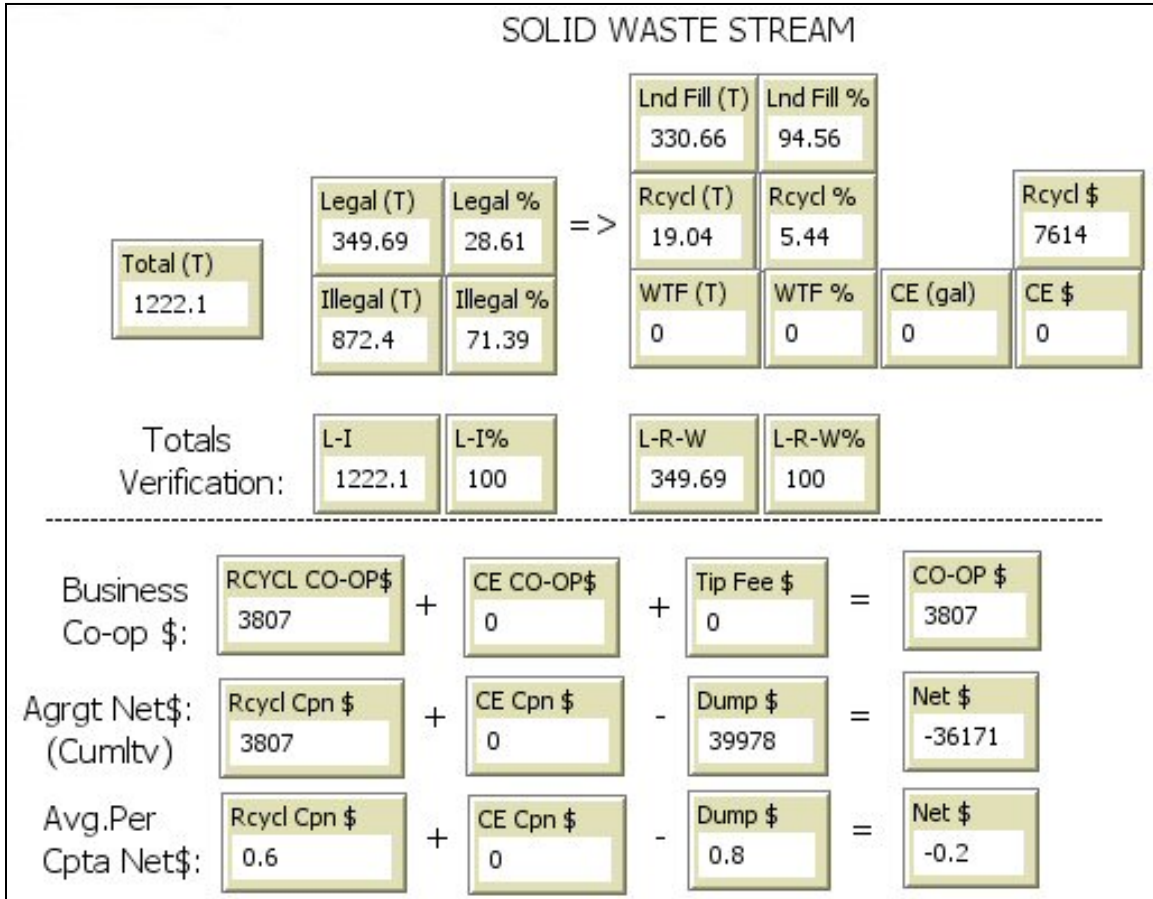


Fig. 4.22 TCL-HEI Tier-II Discovery Trial #2B Data @ 720

This was corroborated by the decline in *uncooperatives* and rise in *cooperatives* (Fig. 4.18 and Fig. 4.21). However, what was really exciting was the news that the waste-to-fuels program had just come on line and was ready to receive solid waste feed stock after

all the recyclables and bio-mass material were removed. It seemed they were going to make it after all.

Nearly four years from the start (1440 iterations) the collaborative effort between the business cooperative members and the Chapter Officials, had paid off and the program was in full forward motion (Fig. 4.23 and Fig. 4.24). *Uncooperatives* were

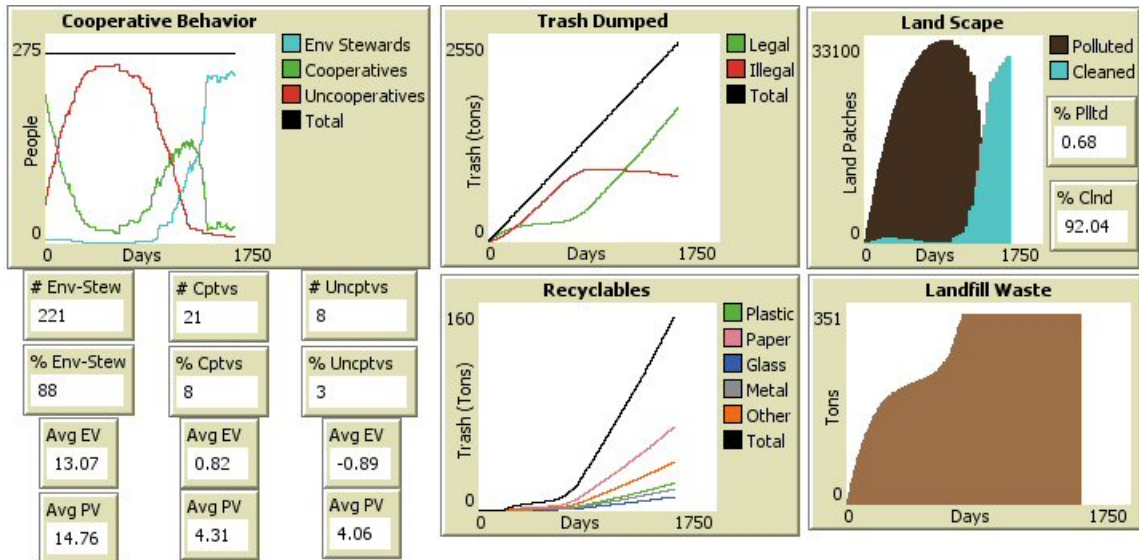


Fig. 4.23 TCL-HEI Tier-II Discovery Trial #2B Plots @ 1440

few and far between (8) and those who were remaining, were just by name as their actions were taking advantage of the improved economics but they remained as *uncooperatives* as their value orientation towards the environment was still negative. There were also fewer *cooperatives* (21) as they had all become *environmental stewards* (221). Illegal trash on the landscape was on the decline and getting cleaned (92%) but none of it was going to the landfill sites as it was all being diverted to recycling or waste-to-fuels, hence the table top look in the ‘Landfill Waste’ plot at around the time the waste-to-fuels program came on line. What’s more, people were netting \$4.58 on average

every time they dumped trash legally whether from their personal places or from landscape clean up efforts (Fig. 4.24). The business cooperative was also doing well with

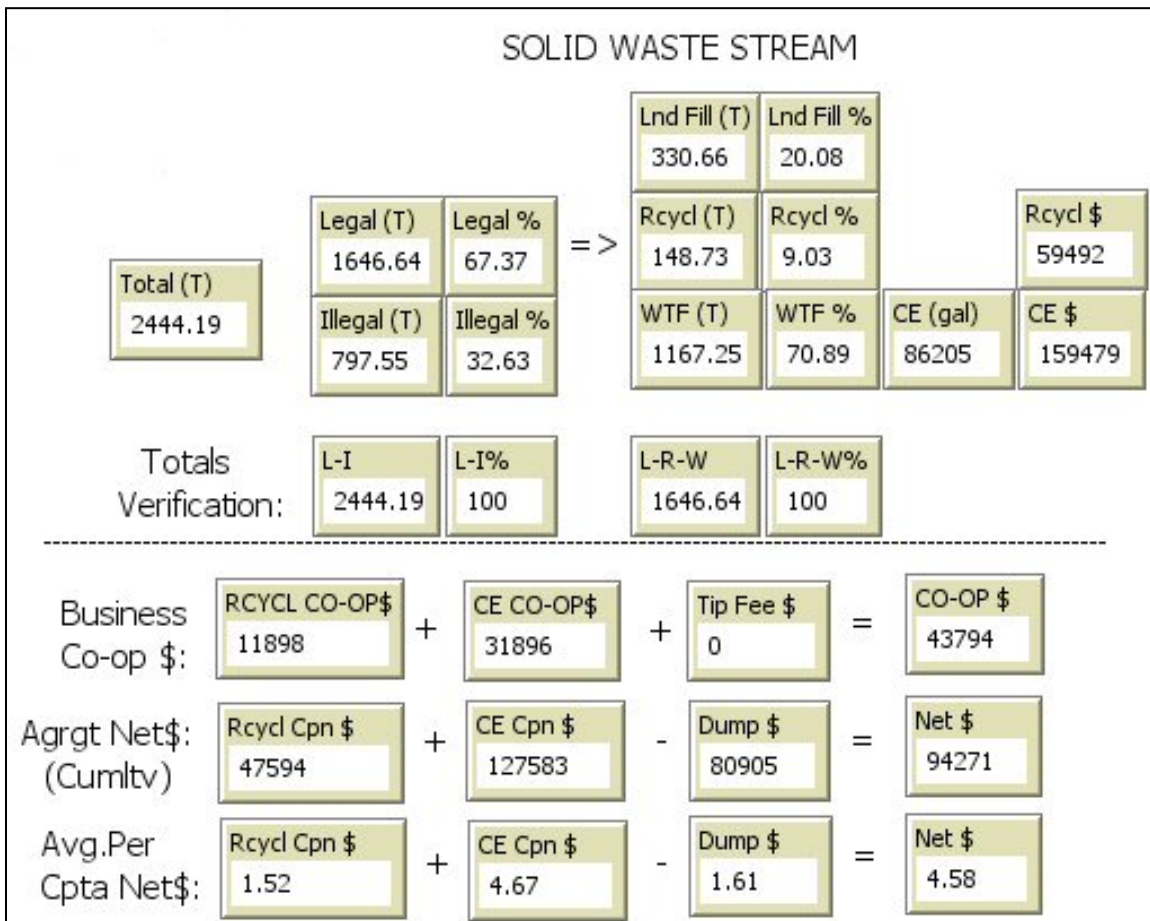


Fig. 4.24 TCL-HEI Tier-II Discovery Trial #2B Data @ 1440

replenished revenues in the amount of \$43,794 and the Officers could now look at alternative community development programs. This revenue comes from the waste-to-fuels (159,479) and recycle (59,492) streams of which 80% was being passed out through coupons to the business coop members and helping to build wealth and capacity within the community.

Life was good, but as the sceanrio would have it, suddenly a shock hits the community when reports break out of a military clash in the Persian Gulf, shooting oil

prices through the roof and gas prices hitting an unprecedented \$7.00 / gal. Was this entrepreneurial initiative going to survive and if it didn't what would that mean for the environment again? To their surprise the model held up (Fig. 4.25 and Fig. 4.26) and was

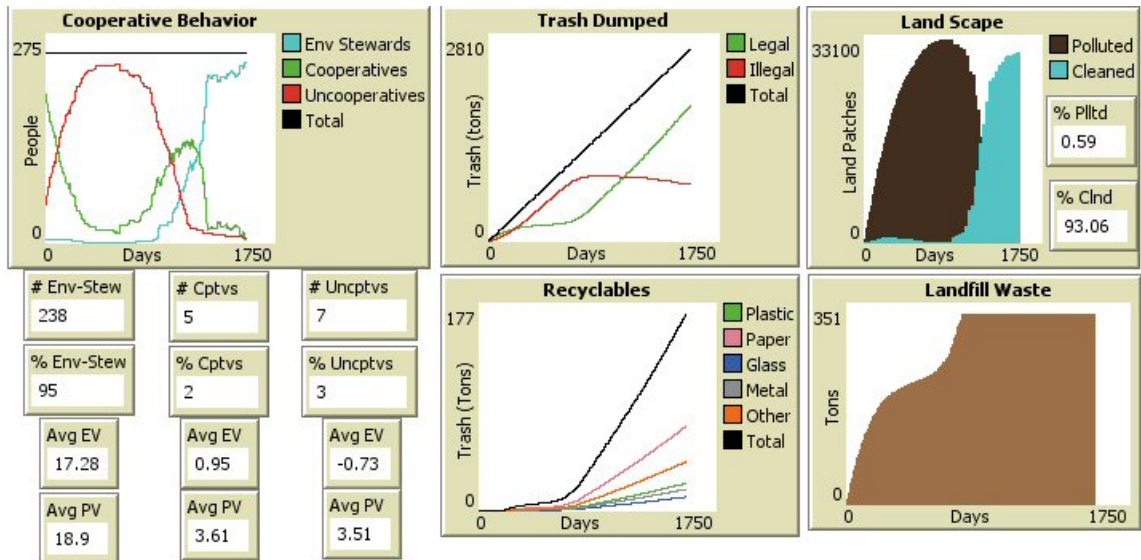


Fig. 4.25 TCL-HEI Tier-II Discovery Trial #2B Data @ 1530

predicting no severe impact from this particular disturbance given the assumptions built into the model, the prediction was that all was in good order and the social-ecological system was able to absorb the shock proving to be not only resilient but ever more sustainable. People were still out cleaning the environment and collecting trash (Fig. 4.27) to trade in for coupons and recycle and clean-energy revenues were strong. To their surprise, they realized that the price shock also impacted ethanol prices that grew their clean-enregy revenue balance and co-op members were being compensated in net\$ at a rate of \$7.61 (Fig. 4.26) in a way that offset the high gasoline prices and still incentivized them to take care of the land.

In conclusion, the local officials in collaboration with the community decided to proceed with a plan towards sustainability by implementing such a recycling and waste-to-fuels program. However, they decided they needed to make a few modifications. First

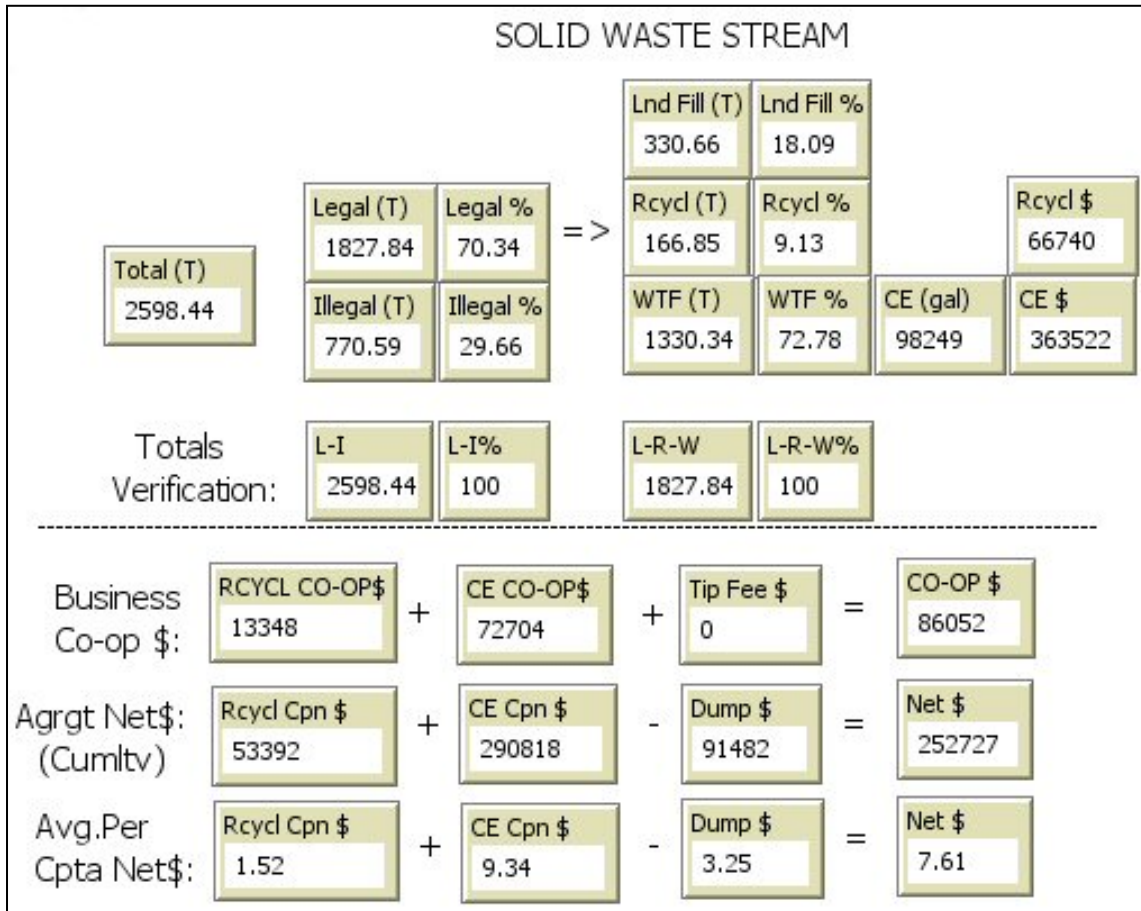


Fig. 4.26 TCL-HEI Tier-II Discovery Trial #2B Data @ 1530

they needed to expand the model in such a way that would bring the full business analysis into view with both revenue and cost streams and to create five year pro forma profit and loss statements, statements of cash flow and balance sheet projections along with a more traditional cost-benefit analysis. Secondly, they realized the power behind such an opportunity to not only protect the environment and create jobs but how it could also become detrimental to the environment if proper checks and balances were not put into

place. This was due to the potential of the waste-to-fuels program. In acting with local, regional and Navajo Nation level authorities they created boundaries that would be strictly enforced to verify waste stream sources and not to accept bio-waste into the program.

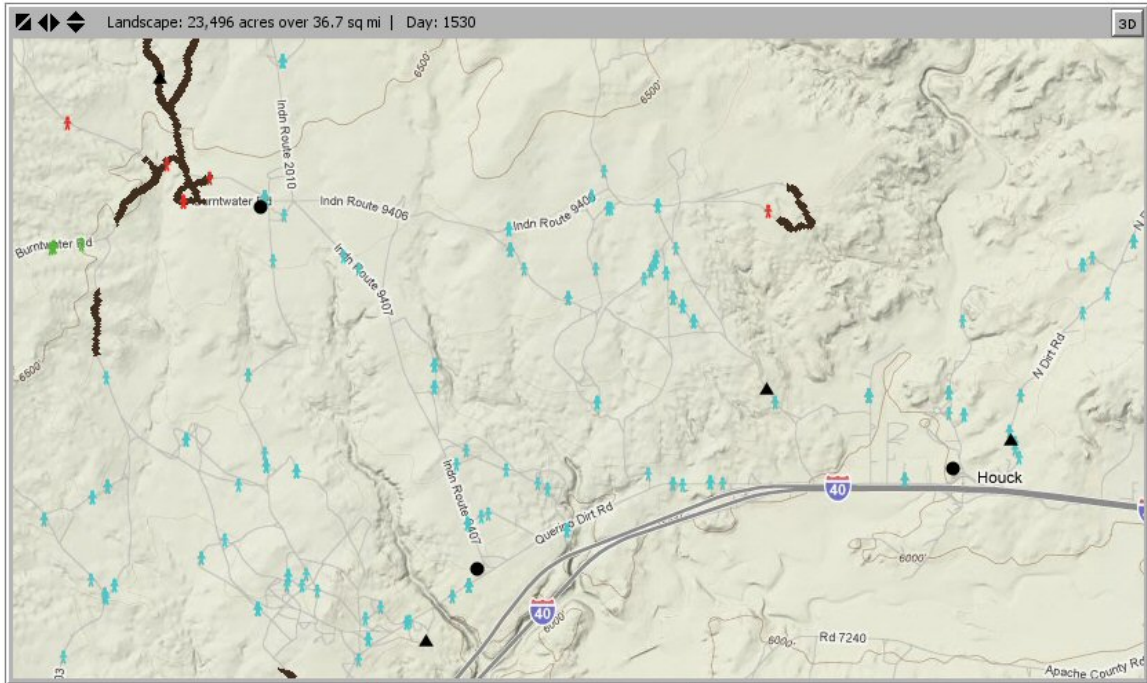


Fig. 4.27 TCL-HEI Tier-II Discovery Trial #2B View @ 1530

All bio-mass such as yard trimmings and cut limbs etc., were to be rerouted into a composting component of the program and there would be no economic incentive given for receiving such waste material. The reason behind this was to protect bio-diversity on the landscape and not create a situation of unintended consequences with this program where people would think they would be able to profit off the landscape by cutting down shrubs, sage and other bio material. To this end, there needed to be an economic disincentive and that would arrive naturally if people knew there was nothing to be gained in such actions. The local planners also realized there could be a negative impact on the already existing trash haulage and landfill program so they vowed to work with

local, regional and Navajo Nation authorities to ensure a fair and equitable transition of job opportunities to those currently working in landfill projects into the new recycle and waste-to-fuels program. That concludes the pro-forma case study.

CONCLUSION

In the final analysis, I believe I have shown how a *Regional Cooperative Clean-Energy Economy* (RCCEE) might look through the lens of the TCL-HEI agent-based model. Further, how such a model could help policy and decision makers evaluate a complex social-ecological system and better understand positive and negative consequences from the implementation of such an environmental-economic program. The resilience and sustainability depicted through this scenario was not just because people were netting a few dollars every time they took out the trash. It was much more than that just as the whole is greater than the sum of the parts. It was not just economic drivers that brought this change about, as the community pulled together there were gatherings and consultations built around the PSFA-CACB conceptual model as discussed in above chapters. There was a sharing of knowledge and information, both scientific and traditional, flowing between communities and regional sites of learning such as Diné College as depicted in the *Regional Cooperative Clean-Energy Economy* (RCCEE) model (Fig.60). It was a result of a community transformed, who together, in a spirit of collaboration were able to adapt and focus on building their own individual and collective capacities to collectively see a problem and find an entrepreneurial solution to that problem that enabled them to guard against vulnerability and disturbance allowing them to live in harmony in a resilient and sustainable social-ecological system.

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APPENDICES

Appendix 4.1 ABM TCL-HEI Tier-I (v9.0) Code

CODE: BRUSS ABM – *Taking Care of the Land-Human Environment Interactions* Tier-I (v9.0)

```
to aaa
end
```

```
globals
```

```
[
  #envstwds
  %envstwds          ; % of the population environmental steward (does not dump illegally and cleans trash)
  %cooptvs           ; % of the population cooperates (do not dump illegal, but do not clean trash)
  #cooptvs
  %uncooptvs        ; % of the population uncooperative (dump illegally and do not clean)
  #uncooptvs
  %patches-polluted ; % of landscape that is polluted
  #patches-polluted
  %pollution-cleaned ; % of polluted landscape that has been cleaned
  #patches-cleaned
  avg-EV-env-stew
  avg-PV-env-stew
  avg-EV-cooperative
  avg-PV-cooperative
  avg-EV-uncooperative
  avg-PV-uncooperative
  trash-dumped
  illegal-trash      ; tracks avg 4.0 lbs/day/person of trash that is dumped illegally by uncooperatives
  illegal-trash%
  ;;; tracks avg 4.0 lbs/day/person of trash that is dumped legally by env stewards and cooperatives
  legal-trash
  legal-trash%
  trash-cleaned
  total-trash        ; legal + illegal trash count
  landfill
  landfill%
  assigned?          ; used in the consult routine to assign and un-assign temp values to a breed

  ;;;verification monitors
  LI
  LI%
]
```

```
breed [ envstwds envstwd ] ; environmental stewards take care of the land, i.e. clean
breed [ cooptvs cooptv ] ; cooperatives will not dump trash illegally but will not go as far as cleaning
;;; uncooperatives have a negative orientation towards the environment and dump illegally and do not clean
breed [ uncooptvs uncooptv ]
breed [ places place ] ; directional targets including chapter house, trading posts, NABI
```

```
envstwds-own
```

```
[
  evaluate          ; environmental values determine the env orientation and strength of conviction
  ;;; persuasion values determine the capacity of consultation, to influence listeners determined by pradius
  ;;;reach
```



```

pvalue
pradius          ; determines sphere of consultative influence
eradius          ; determines sphere of environmental impact - cleaning or illegal dumping
epv              ; temp storage for pvalue used in consult routine
eev              ; temp storage for evalue used in consult routine
finish-place
]

cooptvs-own
[
  evalue          ; environmental values determine the env orientation and strength of conviction
  ;;persuasion values determine the capacity of consultation, to influence listeners determined by pradius
  ;;reach
  pvalue
  pradius          ; determines sphere of consultative influence
  eradius          ; determines sphere of environmental impact - cleaning or illegal dumping
  cpv              ; temp storage for pvalue used in consult routine
  cev              ; temp storage for evalue used in consult routine
  finish-place
]

uncooptvs-own
[
  evalue          ; environmental values determine the env orientation and strength of conviction
  ;; persuasion values determine the capacity of consultation, to influence listeners determined by pradius
  ;;reach
  pvalue
  pradius          ; determines sphere of consultative influence
  eradius          ; determines sphere of environmental impact - cleaning or illegal dumping
  upv              ; temp storage for pvalue used in consult routine
  ; temp storage for evalue used in consult routine finish-place
  uev
]

patches-own
[
  roads
  traveled
  base
  terrain
  sat
  cleaned?
  polluted?
]

to create-seed
  clear-all
  let my-seed new-seed          ;; generate a new seed
  output-print word "Created seed: " my-seed  ;; print it out
  random-seed my-seed          ;; use the new seed
end

to reuse-seed
  clear-all
  let my-seed read-from-string user-input "Enter a random seed (an integer):"
  output-print word "Reused seed: " my-seed          ;; print it out

```

```

    random-seed my-seed                                ;; use the new seed
end

to clear
  clear-all
end

to setup
  setup-maps
  refresh
  setup-patches
  setup-places
  setup-envstwds
  setup-cooptvs
  setup-uncooptvs
  update-monitored-variables
  update-plot
  setup-write-output
end

to setup-maps
  import-pcolors-rgb "C:/Users/PTB/Documents/CSU-PhD/NN-NABI/Field Work/PHASE
III/ABM/Houck/sat.png"
  ask patches [ set sat pcolor ]
  import-pcolors "C:/Users/PTB/Documents/CSU-PhD/NN-NABI/Field Work/PHASE
III/ABM/Houck/roads.png"
  ask patches [ set roads pcolor
  set traveled 0 ]
  import-pcolors-rgb "C:/Users/PTB/Documents/CSU-PhD/NN-NABI/Field Work/PHASE
III/ABM/Houck/base.png"
  ask patches [ set base pcolor ]
  import-pcolors-rgb "C:/Users/PTB/Documents/CSU-PhD/NN-NABI/Field Work/PHASE
III/ABM/Houck/terrain.png"
  ask patches [ set terrain pcolor ]
end

to refresh
  if Landscape = "Roads"
    [ ask patches [ set pcolor roads ] ]
  if Landscape = "Traveled"
    [ ask patches [ set pcolor traveled ] ]
  if Landscape = "Base"
    [ ask patches [ set pcolor base ] ]
  if Landscape = "Terrain"
    [ ask patches [ set pcolor terrain ] ]
  if Landscape = "Satellite"
    [ ask patches [ set pcolor sat ] ]
end

to setup-patches
  ask patches
  [
    set cleaned? true
  ]
end

```

```

to setup-places
  set-default-shape places "circle"
  create-places 3
  [
    set color black
    ifelse places?
      [ set size 10 ]
      [ set size 0 ]
  ]
  ask place 0          ; NABI
  [
    setxy 179 342
  ]
  ask place 1          ; Querino Trading Post
  [
    setxy 681 152
  ]
  ask place 2          ; Houck Chapter House
  [
    setxy 336 79
  ]
end

```

```

to setup-envstwds
  set-default-shape envstwds "person"
  create-envstwds environmental-stewards
  [
    while [ roads < 14.3 or roads > 14.5 ]
      [ setxy random-xcor random-ycor ]
    set color cyan
    set label-color black
    set finish-place one-of places
    let my-elist [ 3 4 5 ]
    set evaluate one-of my-elist
    set eradius (abs evaluate)
    let my-plist [4 6 8 10]
    set pvalue one-of my-plist
    set pradius (abs pvalue)
    set assigned? false
    ifelse people?
      [ set size 10 ]
      [ set size 0 ]
  ]
end

```

```

to setup-cooptvs
  set-default-shape cooptvs "person"
  create-cooptvs cooperatives
  [
    while [ roads < 14.3 or roads > 14.5 ]
      [ setxy random-xcor random-ycor ]
    set color green
    set label-color black
    set finish-place one-of places
    let my-elist [ 0 1 2 ]
    set evaluate one-of my-elist
  ]
end

```

```

    set eradius (abs evalue)
    let my-plist [4 6 8 10]
    set pvalue one-of my-plist
    set pradius (abs pvalue)
    set assigned? false
    ifelse people?
      [ set size 10 ]
      [ set size 0 ]
  ]
end

to setup-uncooptvs
  set-default-shape uncooptvs "person"
  create-uncooptvs uncooperatives
  [
    while [ roads < 14.3 or roads > 14.5 ]
      [ setxy random-xcor random-ycor ]
    set color red
    set label-color black
    set finish-place one-of places
    let my-elist [-3 -2 -1]
    set evalue one-of my-elist
    set eradius (abs evalue)
    let my-plist [4 6 8 10]
    set pvalue one-of my-plist
    set pradius (abs pvalue)
    set assigned? false
    ifelse people?
      [ set size 10 ]
      [ set size 0 ]
  ]
end

to go
  hide
  move
  consult
  dump
  clean
  ask envstwds [ update-radius
    adapt ]
  ask cooptvs [ update-radius
    adapt ]
  ask uncooptvs [ update-radius
    adapt ]
  tick
  update-monitored-variables
  update-plot
  output
  write-output
end

to hide
  ask places
  [ ifelse places?
    [ set size 10 ]
  ]
end

```

```

    [ set size 0 ]
  ]
ask envstwds
  [ ifelse people?
    [ set size 10 ]
    [ set size 0 ]
  ]
ask cooptvs
  [ ifelse people?
    [ set size 10 ]
    [ set size 0 ]
  ]
ask uncooptvs
  [ ifelse people?
    [ set size 10 ]
    [ set size 0 ]
  ]
end

```

```

to move
  ask envstwds
  [
;abs pvalue * 1.5 to represent travel strength based on motivation and charisma
    set traveled traveled + ( abs pvalue * 1.5 )
    ifelse patches in-radius (radius * 3) = polluted?
      [ let trash patches in-radius (radius * 3) with [ polluted? ]
        move-to one-of trash ]
      [ let nearest neighbors with [ roads > 14.3 and roads < 14.5 ]
        move-to min-one-of nearest [ ( distance [ finish-place ] of myself * traveled ) ] ]
  ]
  ask cooptvs
  [
    set traveled traveled + ( abs pvalue * 1.5 )
    let nearest neighbors with [ roads > 14.3 and roads < 14.5 ]
    move-to min-one-of nearest [ ( distance [ finish-place ] of myself * traveled ) ]
  ]
  ask uncooptvs
  [
    set traveled traveled + ( abs pvalue * 1.5 )
    let nearest neighbors with [ roads > 14.3 and roads < 14.5 ]
    move-to min-one-of nearest [ ( distance [ finish-place ] of myself * traveled ) ]
  ]
end

```

```

;;; CONSULT: ASKS EACH AGENT TO LOOK INSIDE ITS P-RADIUS AND INFLUENCE THOSE
;;;WHOSE PVALUES ARE LOWER THAN ITSELF BY ADJUSTING VALUES. SETS PAVLUES
;;;AND EVALUES TO TEMP SETS

```

```

to consult
  ask uncooptvs
  [ if (random 100) < chance-uncooperative
    [ ask cooptvs in-radius pradius
      [ if pvalue < [pvalue] of myself
        ;;; SWITCHED + TO - AS EVALUE NEEDS TO DROP NOT RISE PVALUES ARE ALWAYS
        ;;;POSITIVE, upgrade to v9.0
        [ set cev (evaluate - ([pvalue] of myself) - pvalue)

```

```

        set cpv (pvalue + 1)
        ask myself
        [ set upv (pvalue + 1 )
          set assigned? true
        ]
      ]
    ]
  ]
]
ask envstwds
[ if (random 100) < chance-env-steward
  [ ask cooptvs in-radius pradius
    [ if pvalue < [pvalue] of myself
      [ set cev (evalue + ([pvalue] of myself) - pvalue)
        set cpv (pvalue + 1)
        ask myself
        [ set epv (pvalue + 1 )
          set assigned? true
        ]
      ]
    ]
  ]
]
]
]
ask cooptvs
[ if (random 100) < chance-cooperative
  [ ask uncooptvs in-radius pradius
    [ if [pvalue] of myself > pvalue
      [ set uev (evalue + ([pvalue] of myself) - pvalue)
        set upv (pvalue + 1)
        ask myself
        [ set cpv (pvalue + 1 )
          set assigned? true
        ]
      ]
    ]
  ]
]
]
]
ask envstwds
[ if (random 100) < chance-env-steward
  [ ask uncooptvs in-radius pradius
    [ if pvalue < [pvalue] of myself
      [ set uev (evalue + ([pvalue] of myself) - pvalue)
        set upv (pvalue + 1)
        ask myself
        [ set epv (pvalue + 1 )
          set assigned? true
        ]
      ]
    ]
  ]
]
]
]
];; SWAP TEMP VALUES BACK TO TRUE VALUES
ask uncooptvs
[if assigned?
  [ ask cooptvs in-radius pradius

```

```

;;; CHANGED < to > TO UPGRADE TO v9.0 // if cooptvs evalue is > uncooptvs then cooptv value
;;;orientation shift was not sufficient in consultation to adapt
  [ ifelse cev > [evalue] of myself
    [ set evalue cev
      set cev 0
    ]
    [ set evalue [evalue] of myself
      set cev 0
    ]
  ]
  if pvalue < [pvalue] of myself
    [ set pvalue cpv
      set cpv 0
      ask myself
        [ set pvalue upv
          set upv 0
          set assigned? false
        ]
    ]
  ]
]
]
]
]
ask cooptvs
[if assigned?
  [ ask uncooptvs in-radius pradius
    [ ifelse uev < [evalue] of myself
      [ set evalue uev
        set uev 0
      ]
      [ set evalue [evalue] of myself
        set uev 0
      ]
    ]
    if pvalue < [pvalue] of myself
      [ set pvalue upv
        set upv 0
        ask myself
          [ set pvalue cpv
            set cpv 0
            set assigned? false
          ]
      ]
    ]
  ]
]
]
]
]
ask envstws
[if assigned?
  [ ask uncooptvs in-radius pradius
    [ ifelse uev < [evalue] of myself
      [ set evalue uev
        set uev 0
      ]
      [ set evalue [evalue] of myself
        set uev 0
      ]
    ]
    if pvalue < [pvalue] of myself
      [ set pvalue upv

```

```

    set upv 0
    ask myself
      [ set pvalue epv
        set epv 0
        set assigned? false
      ]
    ]
  ]
]
]
]
ask envstwds
[if assigned?
  [ ask cooptvs in-radius pradius
    [ ifelse cev < [evaluate] of myself
      [ set evaluate cev
        set cev 0
      ]
      [ set evaluate [evaluate] of myself
        set cev 0
      ]
    ]
  if pvalue < [pvalue] of myself
    [ set pvalue cpv
      set cpv 0
      ask myself
        [ set pvalue epv
          set epv 0
          set assigned? false
        ]
    ]
  ]
]
]
]
end

```

```

;;; DUMP: AVG DAILY TRASH/PERSON ON NN IS EST. 4lbs
;;; NATIONAL AVG. IS 4.43 lbs/PERSON
;;; MODEL BASED ON HOUSEHOLDS WITH 3.39 PEOPLE/HH
;;; HOUCK TIPPING FEE IS $1.00 / BAG (avg bag wght = 10lbs )
;;; REPORTED IN TONS (lbs / 2000)

```

```

to dump
  if dump?
    [ if ticks mod dump-once-per = 0 ; ticks mod = 0 is setting for true
      [ ask uncooptvs
        [ set trash-dumped (trash-dmpd/prsn * 3.39) * dump-once-per / 2000
          set illegal-trash illegal-trash + trash-dumped
          if trash-dmpd/prsn > 0
            ;;; not to scale, just used as a visual indicator of illegal trash dumping
            [ ask patches in-radius (trash-dmpd/prsn / 3)
              [ set pcolor 32
                set polluted? true
                set cleaned? false
              ]
            ]
          ]
        ]
      ]
    ]
  ask cooptvs

```



```

    [ set trash-dumped (trash-dmpd/prsn * 3.39) * dump-once-per / 2000
      set legal-trash legal-trash + trash-dumped
      set landfill landfill + (trash-dmpd/prsn * 3.39) * dump-once-per / 2000
    ]
  ask envstwds
  [ set trash-dumped (trash-dmpd/prsn * 3.39) * dump-once-per / 2000
    set legal-trash legal-trash + trash-dumped
    set landfill landfill + (trash-dmpd/prsn * 3.39) * dump-once-per / 2000
  ]
]
]
end

to clean
  if clean?
    [ if ticks mod clean-once-per = 0
      [ ask envstwds
        ;; can only clean trash if it exists, prevents negative illegal trash count
        [ ifelse illegal-trash - ( trash-clnd/prsn / 2000 ) >= 0
          [ set illegal-trash illegal-trash - ( trash-clnd/prsn / 2000 )
            set legal-trash legal-trash + ( trash-clnd/prsn / 2000 )
            set landfill landfill + ( trash-clnd/prsn / 2000 )
          ;; not to scale, just used as a visual indicator of illegal trash cleanup
          ask patches in-radius ( trash-clnd/prsn / 2 )
          [
            if Landscape = "Base" and cleaned? = false
            [ set cleaned? true
              set polluted? false
              set pcolor base
            ]
            if Landscape = "Roads" and cleaned? = false
            [ set cleaned? true
              set polluted? false
              set pcolor roads
            ]
            if Landscape = "Traveled" and cleaned? = false
            [ set cleaned? true
              set polluted? false
              set pcolor sat
            ]
            if Landscape = "Satellite" and cleaned? = false
            [ set cleaned? true
              set polluted? false
              set pcolor sat
            ]
            if Landscape = "Terrain" and cleaned? = false
            [ set cleaned? true
              set polluted? false
              set pcolor terrain
            ]
          ]
        ]
        ;;ELSE illegal-trash - trash-clnd/prsn >= 0
        [ set illegal-trash 0
          set legal-trash legal-trash + (( trash-clnd/prsn / 2000 ) - ( ( trash-clnd/prsn / 2000 ) - illegal-trash ) )
        ;; to set legal trash exactly what is cleaned to prevent going negative

```

```

    set landfill landfill + (( trash-clnd/prsn / 2000 ) - ( ( trash-clnd/prsn / 2000 ) - illegal-trash ))
;;; not to scale, just used as a visual indicator of illegal trash cleanup
ask patches in-radius ( trash-clnd/prsn / 2 )
[
  if Landscape = "Base" and cleaned? = false
  [ set cleaned? true
    set polluted? false
    set pcolor base
  ]
  if Landscape = "Roads" and cleaned? = false
  [ set cleaned? true
    set polluted? false
    set pcolor roads
  ]
  if Landscape = "Traveled" and cleaned? = false
  [ set cleaned? true
    set polluted? false
    set pcolor sat
  ]
  if Landscape = "Satellite" and cleaned? = false
  [ set cleaned? true
    set polluted? false
    set pcolor sat
  ]
  if Landscape = "Terrain" and cleaned? = false
  [ set cleaned? true
    set polluted? false
    set pcolor terrain
  ]
]
]
]
]
;;; OBSERVER CONTEXT - to clear landscape pollution (that is for visual affect only and not to scale)
;;;when illegal trash statistic (the measure being used) = 0
if illegal-trash - ( trash-clnd/prsn / 2000 ) < 0
[ ask patches
  [ if Landscape = "Base" and cleaned? = false
    [ set cleaned? true
      set polluted? false
      set pcolor base
    ]
  if Landscape = "Roads" and cleaned? = false
  [ set cleaned? true
    set polluted? false
    set pcolor roads
  ]
  if Landscape = "Traveled" and cleaned? = false
  [ set cleaned? true
    set polluted? false
    set pcolor sat
  ]
  if Landscape = "Satellite" and cleaned? = false
  [ set cleaned? true
    set polluted? false
    set pcolor sat
  ]
]
]
]
]

```

```

    ]
  if Landscape = "Terrain" and cleaned? = false
    [ set cleaned? true
      set polluted? false
      set pcolor terrain
    ]
  ]
]
]
end

to update-radius
  set eradius ( abs evalue )
  set pradius ( abs pvalue )
end

to adapt
  if evalue >= 3 [ be-env-stew ]
  if evalue >= 0 and evalue < 3 [ be-cooperative ]
  if evalue < 0 [ be-uncooperative ]
end

to be-uncooperative
  set breed uncooptvs
  set color red
end

to be-env-stew
  set breed envstwds
  set color cyan
end

to be-cooperative
  set breed cooptvs
  set color green
end

to update-monitored-variables
  set #envstwds count envstwds
  set #cooptvs count cooptvs
  set #uncooptvs count uncooptvs
  ifelse count envstwds > 0
    [ set %envstwds (count envstwds) / (count envstwds + count cooptvs + count uncooptvs) * 100 ]
    [ set %envstwds "0.00" ]
  ifelse count cooptvs > 0
    [ set %cooptvs (count cooptvs) / (count envstwds + count cooptvs + count uncooptvs) * 100 ]
    [ set %cooptvs "0.00" ]
  ifelse count uncooptvs > 0
    [ set %uncooptvs (count uncooptvs) / (count envstwds + count cooptvs + count uncooptvs) * 100 ]
    [ set %uncooptvs "0.00" ]
  ;;; to report each patch in acres, 1 patch here is = 2692 sq ft / 43560 sq ft per acre
  set #patches-polluted count patches with [ polluted? = true ] * (2692 / 43560)
  set %patches-polluted (count patches with [ polluted? = true ] ) / (count patches) * 100
  ;;; to report in acres
  set #patches-cleaned count patches with [ polluted? = false ] * (2692 / 43560)
  ifelse (count patches with [ polluted? = false ] + count patches with [ polluted? = true ]) > 0

```

```

    [ set %pollution-cleaned (count patches with [ polluted? = false ]) / (count patches with [ polluted? =
false ] + count patches with [ polluted? = true ]) * 100 ]
    [ set %pollution-cleaned "0.00" ]
    ifelse count envstwds > 0
    [ set avg-EV-env-stew (sum [evalue] of envstwds) / count envstwds ]
    [ set avg-EV-env-stew "0.00" ]
    ifelse count envstwds > 0
    [ set avg-PV-env-stew (sum [pvalue] of envstwds) / count envstwds ]
    [ set avg-PV-env-stew "0.00" ]
    ifelse count cooptvs > 0
    [ set avg-EV-cooperative (sum [evalue] of cooptvs) / count cooptvs ]
    [ set avg-EV-cooperative "0.00" ]
    ifelse count cooptvs > 0
    [ set avg-PV-cooperative (sum [pvalue] of cooptvs) / count cooptvs ]
    [ set avg-PV-cooperative "0.00" ]
    ifelse count uncooptvs > 0
    [ set avg-EV-uncooperative (sum [evalue] of uncooptvs) / count uncooptvs ]
    [ set avg-EV-uncooperative "0.00" ]
    ifelse count uncooptvs > 0
    [ set avg-PV-uncooperative (sum [pvalue] of uncooptvs) / count uncooptvs ]
    [ set avg-PV-uncooperative "0.00" ]

set LI legal-trash + illegal-trash
set LI% legal-trash% + illegal-trash%
set total-trash illegal-trash + legal-trash
if total-trash > 0
    [ set legal-trash% legal-trash / total-trash * 100
    set illegal-trash% illegal-trash / total-trash * 100
    ]
if legal-trash > 0
    [set landfill% landfill / legal-trash * 100 ]
end

to update-plot
set-current-plot "Cooperative Behavior"
set-current-plot-pen "Cooperatives"
plot count cooptvs
set-current-plot-pen "Uncooperatives"
plot count uncooptvs
set-current-plot-pen "Env Stewards"
plot count envstwds
set-current-plot-pen "Total"
plot (count envstwds + count cooptvs + count uncooptvs)
set-current-plot "Landscape"
set-current-plot-pen "Polluted"
plot count patches with [ pcolor = 32 ]
set-current-plot-pen "Cleaned"
plot count patches with [ polluted? = false ]
set-current-plot "Trash Dumped"
set-current-plot-pen "Illegal"
plot illegal-trash
set-current-plot-pen "Legal"
plot legal-trash
set-current-plot-pen "Total"
plot (legal-trash + illegal-trash)
set-current-plot "Landfill Waste"

```

```

plot landfill
end

to output
  if output?
    [ output-show (word "3/12/12(v9.0Tier-I)Trl#1DSCVRY#1C: Incentives 5e%50 195c%25 50u%5
40lbs30dys")

; ; output-show (word "----- Day: " ticks "-----")
; ; ask envstwds [ output-show (word "EVALUE: " precision evaluate 0 " PVALUE: " precision
pvalue 0 ) ]
; output-show "" ;; blank line
; ask cooptvs [ output-show (word "EVALUE: " precision evaluate 0 " PVALUE: " precision pvalue 0
) ]
; output-show "" ;; blank line
; ask uncooptvs [ output-show (word "EVALUE: " precision evaluate 0 " PVALUE: " precision
pvalue 0 ) ]
; output-show "" ;; blank line
]
end

to setup-write-output
  if write?
    [ let file user-new-file
      if is-string? file
        [if file-exists? file
          [file-delete file]
        ]
      file-open file
    ]
  ]
  ; write-output
end

to write-output
  if write?
    [
      file-print (word "----- Day: " ticks "-----")
      ask envstwds
      [ file-print (word self ": evaluate: " evaluate " pvalue: " pvalue) ]
      file-print "" ;; blank line
    ]
  ]
end

```

```

;;; Copyright 2011 onwards Peter T Bruss. All rights reserved.
;;; Dissertation work through Colorado State University

```

Appendix 4.2. ABM TCL-HEI Tier-I & II (v9.2) Code

CODE: BRUSS ABM – *Taking Care of the Land-Human Environment Interactions* Tier-II (v9.2)

to aaa
end

globals

[

```

#envstwds
%envstwds          ; % of the population environmental steward (does not dump illegally and cleans trash)
%cooptvs           ; % of the population cooperates (do not dump illegal, but do not clean trash)
#cooptvs
%uncooptvs        ; % of the population uncooperative (dump illegally and do not clean)
#uncooptvs
%patches-polluted ; % of landscape that is polluted
#patches-polluted
%pollution-cleaned ; % of polluted landscape that has been cleaned
#patches-cleaned
avg-EV-env-stew
avg-PV-env-stew
avg-EV-cooperative
avg-PV-cooperative
avg-EV-uncooperative
avg-PV-uncooperative
trash-dumped
illegal-trash      ; tracks avg 4.0 lbs/day/person of trash that is dumped illegally by uncooperatives
illegal-trash%
legal-trash        ; tracks avg 4.0 lbs/day/person of trash that is dumped legally by env stewards and
cooperatives
legal-trash%
trash-cleaned
total-trash        ; legal + illegal trash count
tip$fee
recycled-trash     ; NN estimate is at 10% of total collected trash
recycled-trash%
landfill
landfill%
wtf-trash          ; waste-to-fuels trash is the end stream trash after recycling. It is what would go to land fill
wtf-trash%
assigned?          ; used in the consult routine to assign and un-assign temp values to a breed
recycled$
rcycl$coop
rcycl$cpn
rcycl$cpn-pc
ce$cpn
ce$cpn-pc
;;; 1 ton msw yields est. 95 gal. ethanol(i.e. 1 lb yields .0475 gal.). Feb. 2010 market ethanol prices were
;;; about $1.85 / gal.
ce-gal
ce$
ce$coop
dump$

```

dump\$-pc
 legaldump\$
 illegaldump\$
 net\$
 net\$-pc
 coop\$
 ;;verification monitors
 LI
 LI%
 LRW
 LRW%
]

breed [envstwds envstwd] ; environmental stewards take care of the land, i.e. clean
 breed [cooptvs cooptv] ; cooperatives will not dump trash illegally but will not go as far as cleaning
 ;; uncooperatives have a negative orientation towards the environment and dump illegally and do not clean
 breed [uncooptvs uncooptv]
 breed [places place] ; directional targets include chapter house, trading posts, NABI, trash sites
 breed [illegal-ds illegal-d] ; illegal dump sites - total of 3 large ones

envstwds-own
 [
 evaluate ; environmental values determine the env orientation and strength of conviction
 ;; persuasion values determine the capacity of consultation, to influence listeners determined by pradius
 ;; reach
 pvalue
 pradius ; determines sphere of consultative influence
 eradius ; determines sphere of environmental impact - cleaning or illegal dumping
 epv ; temp storage for pvalue used in consult routine
 eev ; temp storage for evaluate used in consult routine
 finish-place
 myrcycl\$cpn
 myce\$cpn
 myce-gal
 mynet\$
 distance-cp
 distance-id
 mydump\$
 mynet\$cp
 mynet\$id
]

cooptvs-own
 [
 evaluate
 pvalue
 pradius
 eradius
 cpv
 cev
 finish-place
 myrcycl\$cpn
 myce\$cpn
 myce-gal
 mynet\$
 distance-cp

```

distance-id
mydump$
mynet$cp
mynet$id
]

```

```

uncooptvs-own
[
  evaluate
  pvalue
  pradius
  eradius
  upv
  uev
  finish-place
  myrcycl$cpn
  myce$cpn
  myce-gal
  mynet$
  distance-cp
  distance-id
  mydump$
  mynet$cp?
  mynet$id?
]

```

```

patches-own
[
  roads
  traveled
  base
  terrain
  sat
  cleaned?
  polluted?
]

```

```

illegal-ds-own
[
  distance-id
]

```

```

to create-seed                                     ;; seed code from NetLogo seed example
  clear-all
  let my-seed new-seed                             ;; generate a new seed
  output-print word "Created seed: " my-seed       ;; print it out
  random-seed my-seed                              ;; use the new seed
end

```

```

to reuse-seed
  clear-all
  let my-seed read-from-string user-input "Enter a random seed (an integer):"
  output-print word "Reused seed: " my-seed       ;; print it out
  random-seed my-seed                             ;; use the new seed
end

```



```

to clear
  clear-all
end

to setup
  setup-maps
  refresh
  setup-patches
  setup-places
  setup-illegal-ds
  setup-envstwds
  setup-cooptvs
  setup-uncooptvs
  update-monitored-variables
  update-plot
  setup-write-output
end

to setup-maps
  import-pcolors-rgb "C:/Users/PTB/Documents/CSU-PhD/NN-NABI/Field Work/PHASE
III/ABM/Houck/sat.png"
  ask patches [ set sat pcolor ]
  import-pcolors "C:/Users/PTB/Documents/CSU-PhD/NN-NABI/Field Work/PHASE
III/ABM/Houck/roads.png"
  ask patches [ set roads pcolor
  set traveled 0 ]
  import-pcolors-rgb "C:/Users/PTB/Documents/CSU-PhD/NN-NABI/Field Work/PHASE
III/ABM/Houck/base.png"
  ask patches [ set base pcolor ]
  import-pcolors-rgb "C:/Users/PTB/Documents/CSU-PhD/NN-NABI/Field Work/PHASE
III/ABM/Houck/terrain.png"
  ask patches [ set terrain pcolor ]
end

to refresh
  if Landscape = "Roads"
    [ ask patches [ set pcolor roads ] ]
  if Landscape = "Traveled"
    [ ask patches [ set pcolor traveled ] ]
  if Landscape = "Base"
    [ ask patches [ set pcolor base ] ]
  if Landscape = "Terrain"
    [ ask patches [ set pcolor terrain ] ]
  if Landscape = "Satellite"
    [ ask patches [ set pcolor sat ] ]
end

to setup-patches
  ask patches
  [
    set cleaned? true
  ]
end

to setup-places
  set-default-shape places "circle"

```

```

create-places 3
[
  set color black
  ifelse places?
    [ set size 10 ]
    [ set size 0 ]
]
ask place 0          ; NABI
[
  setxy 179 342
]
ask place 1          ; Querino Trading Post
[
  setxy 681 152
]
ask place 2          ; Houck Chapter House
[
  setxy 336 79
]
end

```

```

to setup-illegal-ds
  set-default-shape illegal-ds "triangle"
  create-illegal-ds 4
  [ set color black
    ifelse places?
      [ set size 12 ]
      [ set size 0 ]
  ]
  ask illegal-d 3
  [ setxy 723 173 ]
  ask illegal-d 4
  [ setxy 299 27 ]
  ask illegal-d 5
  [ setxy 106 436 ]
  ask illegal-d 6
  [ setxy 546 210 ]
end

```

```

to setup-envstwds
  set-default-shape envstwds "person"
  create-envstwds environmental-stewards
  [
    while [ roads < 14.3 or roads > 14.5 ]
      [ setxy random-xcor random-ycor ]
    set color cyan
    set label-color black
    set finish-place one-of places
    let my-elist [ 3 4 5 ]
    set evaluate one-of my-elist
    set eradius (abs evaluate)
    let my-plist [4 6 8 10]
    set pvalue one-of my-plist
    set pradius (abs pvalue)
    set assigned? false
    set distance-cp distance [ place 1 ] of self * 52 / 5280
  ]
end

```

```

    set distance-id distance (min-one-of illegal-ds [ distance myself ] ) * 52 / 5280
    ifelse people?
      [ set size 10 ]
      [ set size 0 ]
  ]
end

to setup-cooptvs
  set-default-shape cooptvs "person"
  create-cooptvs cooperatives
  [
    while [ roads < 14.3 or roads > 14.5 ]
      [ setxy random-xcor random-ycor ]
    set color green
    set label-color black
    set finish-place one-of places
    let my-elist [ .75 1 2 ] ; .75 avoids sitting on margin uncooperatives to prevent a jump at the start
    set evaluate one-of my-elist
    set eradius (abs evaluate)
    let my-plist [4 6 8 10]
    set pvalue one-of my-plist
    set pradius (abs pvalue)
    set assigned? false
    set distance-cp distance [ place 1 ] of self * 52 / 5280
    set distance-id distance (min-one-of illegal-ds [ distance myself ] ) * 52 / 5280
    ifelse people?
      [ set size 10 ]
      [ set size 0 ]
  ]
end

to setup-uncooptvs
  set-default-shape uncooptvs "person"
  create-uncooptvs uncooperatives
  [
    while [ roads < 14.3 or roads > 14.5 ]
      [ setxy random-xcor random-ycor ]
    set color red
    set label-color black
    set finish-place one-of places
    let my-elist [-3 -2 -1]
    set evaluate one-of my-elist
    set eradius (abs evaluate)
    let my-plist [4 6 8 10]
    set pvalue one-of my-plist
    set pradius (abs pvalue)
    set assigned? false
    set distance-cp distance [ place 1 ] of self * 52 / 5280
    set distance-id distance (min-one-of illegal-ds [ distance myself ] ) * 52 / 5280
    ifelse people?
      [ set size 10 ]
      [ set size 0 ]
  ]
end

to go

```

```

hide
move
consult
dump
clean
ask envstwds [ update-radius
  adapt ]
ask cooptvs [ update-radius
  adapt ]
ask uncooptvs [ update-radius
  adapt ]
tick
update-monitored-variables
update-plot
output
write-output
end

```

```

to hide
  ask places
    [ ifelse places?
      [ set size 10 ]
      [ set size 0 ]
    ]
  ask illegal-ds
    [ ifelse places?
      [ set size 12 ]
      [ set size 0 ]
    ]
  ask envstwds
    [ ifelse people?
      [ set size 10 ]
      [ set size 0 ]
    ]
  ask cooptvs
    [ ifelse people?
      [ set size 10 ]
      [ set size 0 ]
    ]
  ask uncooptvs
    [ ifelse people?
      [ set size 10 ]
      [ set size 0 ]
    ]
end

```

```

to move
  ask envstwds
    [
    ;;;abs pvalue * 1.5 to represent travel strength based on motivation and charisma
    set traveled traveled + ( abs pvalue * 1.5 )
    ifelse patches in-radius (eradius * 3) = polluted?
      [ let trash patches in-radius (eradius * 3) with [ polluted? ]
        move-to one-of trash ]
      [ let nearest neighbors with [ roads > 14.3 and roads < 14.5 ]

```

```

    move-to min-one-of nearest [ ( distance [ finish-place ] of myself * traveled ) ] ]
  ]
ask cooptvs
[
  set traveled traveled + ( abs pvalue * 1.5 )
  let nearest neighbors with [ roads > 14.3 and roads < 14.5 ]
  move-to min-one-of nearest [ ( distance [ finish-place ] of myself * traveled ) ]
]
ask uncooptvs
[
  set traveled traveled + ( abs pvalue * 1.5 )
  let nearest neighbors with [ roads > 14.3 and roads < 14.5 ]
  move-to min-one-of nearest [ ( distance [ finish-place ] of myself * traveled ) ]
]
end

;;; CONSULT: ASKS EACH AGENT TO LOOK INSIDE ITS P-RADIUS AND INFLUENCE THOSE
;;; WHOSE PVALUES ARE LOWER THAN ITSELF BY ADJUSTING VALUES. SETS PAVLUES
;;; AND EVALUES TO TEMP SETS
to consult
  ifelse economics?
  [
    ask uncooptvs
    [ if (random 100) < chance-uncooperative
      [ ask cooptvs in-radius pradius
        ;; brings economics into the consultation uncooperative influences (-) due to bad economics
        [ if pvalue < [pvalue] of myself and [ mynet$ ] of myself <= 0
          [ set cev (evalue - ([pvalue] of myself) - pvalue)
            set cpv (pvalue + 1)
            ask myself
            [ set upv (pvalue + 1 )
              set assigned? true
            ]
          ]
        ]
      ]
    ]
  ]
ask envstwds
[ if (random 100) < chance-env-steward
  [ ask cooptvs in-radius pradius
    [ if pvalue < [pvalue] of myself and [ mynet$ ] of myself >= 0
      [ set cev (evalue + ([pvalue] of myself) - pvalue)
        set cpv (pvalue + 1)
        ask myself
        [ set epv (pvalue + 1 )
          set assigned? true
        ]
      ]
    ]
  ]
]
ask cooptvs
[ if (random 100) < chance-cooperative
  [ ask uncooptvs in-radius pradius
    [ if pvalue < [pvalue] of myself and [ mynet$ ] of myself >= 0
      [ set uev (evalue + ([pvalue] of myself) - pvalue)

```

```

    set upv (pvalue + 1)
    ask myself
      [ set cpv (pvalue + 1 )
        set assigned? true
      ]
    ]
  ]
]
]
ask uncooptvs
[ if (random 100) < chance-uncooperative
  [ ask envstws in-radius pradius
    [ if pvalue < [pvalue] of myself and [ mynet$ ] of myself <= 0
      [ set eev (evalue - ([pvalue] of myself) - pvalue)
        set epv (pvalue + 1)
        ask myself
          [ set upv (pvalue + 1 )
            set assigned? true
          ]
        ]
      ]
    ]
  ]
]
ask envstws
[ if (random 100) < chance-env-steward
  [ ask uncooptvs in-radius pradius
    [ if pvalue < [pvalue] of myself and [ mynet$ ] of myself >= 0
      [ set uev (evalue + ([pvalue] of myself) - pvalue)
        set upv (pvalue + 1)
        ask myself
          [ set epv (pvalue + 1 )
            set assigned? true
          ]
        ]
      ]
    ]
  ]
]
]
ask cooptvs
[ if (random 100) < chance-cooperative
  [ ask envstws in-radius pradius
    [ if pvalue < [pvalue] of myself and [ mynet$ ] of myself >= 0
      [ set eev (evalue + ([pvalue] of myself) - pvalue)
        set epv (pvalue + 1)
        ask myself
          [ set cpv (pvalue + 1 )
            set assigned? true
          ]
        ]
      ]
    ]
  ]
]
];; SWAP TEMP VALUES BACK TO TRUE VALUES
ask uncooptvs
[if assigned?          ;;; if assigned? means if a consultation took place that resulted in a persuasion
  [ ask cooptvs in-radius pradius
    [ ifelse cev > [evalue] of myself

```

```

    [ set evalue cev
      set cev 0
    ]
    [ set evalue [evalue] of myself
      set cev 0
    ]
    if pvalue < [pvalue] of myself
      [ set pvalue cpv
        set cpv 0
        ask myself
          [ set pvalue upv
            set upv 0
            set assigned? false
          ]
        ]
      ]
    ]
  ]
]
ask cooptvs
[if assigned?
  [ ask uncooptvs in-radius pradius
    [ ifelse uev < [evalue] of myself
      [ set evalue uev
        set uev 0
      ]
      [ set evalue [evalue] of myself
        set uev 0
      ]
    ]
    if pvalue < [pvalue] of myself
      [ set pvalue upv
        set upv 0
        ask myself
          [ set pvalue cpv
            set cpv 0
            set assigned? false
          ]
        ]
      ]
    ]
  ]
]
ask uncooptvs
[if assigned?
  [ ask envstws in-radius pradius
    [ ifelse eev > [evalue] of myself
      [ set evalue eev
        set eev 0
      ]
      [ set evalue [evalue] of myself
        set eev 0
      ]
    ]
    if pvalue < [pvalue] of myself
      [ set pvalue epv
        set epv 0
        ask myself
          [ set pvalue upv
            set upv 0
          ]
        ]
      ]
    ]
  ]
]

```

```

        set assigned? false
    ]
]
]
]
]
ask envstwds
[if assigned?
  [ ask uncooptvs in-radius pradius
    [ ifelse uev < [evaluate] of myself
      [ set evaluate uev
        set uev 0
      ]
      [ set evaluate [evaluate] of myself
        set uev 0
      ]
    ]
    if pvalue < [pvalue] of myself
      [ set pvalue upv
        set upv 0
        ask myself
          [ set pvalue epv
            set epv 0
            set assigned? false
          ]
      ]
    ]
]
]
]
]
ask envstwds
[if assigned?
  [ ask cooptvs in-radius pradius
    [ ifelse cev < [evaluate] of myself
      [ set evaluate cev
        set cev 0
      ]
      [ set evaluate [evaluate] of myself
        set cev 0
      ]
    ]
    if pvalue < [pvalue] of myself
      [ set pvalue cpv
        set cpv 0
        ask myself
          [ set pvalue epv
            set epv 0
            set assigned? false
          ]
      ]
    ]
]
]
]
]
ask cooptvs
[if assigned?
  [ ask envstwds in-radius pradius
    [ ifelse eev < [evaluate] of myself
      [ set evaluate eev
        set eev 0

```



```

]
[ set evalue [evalue] of myself
  set eev 0
]
if pvalue < [pvalue] of myself
[ set pvalue epv
  set epv 0
  ask myself
  [ set pvalue cpv
    set cpv 0
    set assigned? false
  ]
]
]
]
]
]
]
];;ELSE CONSULT WITHOUT INFLUENCE OF ECONOMICS WHERE ENVSTWDS ARE NOT
INFLUENCED NEGATIVELY, SAME AS TIER-I ROUTINE
[
ask uncooptvs
[ if (random 100) < chance-uncooperative
[ ask cooptvs in-radius pradius
[ if pvalue < [pvalue] of myself
[ set cev (evalue - ([pvalue] of myself) - pvalue)
  set cpv (pvalue + 1)
  ask myself
  [ set upv (pvalue + 1 )
    set assigned? true
  ]
]
]
]
]
]
ask envstwds
[ if (random 100) < chance-env-steward
[ ask cooptvs in-radius pradius
[ if pvalue < [pvalue] of myself
[ set cev (evalue + ([pvalue] of myself) - pvalue)
  set cpv (pvalue + 1)
  ask myself
  [ set epv (pvalue + 1 )
    set assigned? true
  ]
]
]
]
]
]
ask cooptvs
[ if (random 100) < chance-cooperative
[ ask uncooptvs in-radius pradius
[ if [pvalue] of myself > pvalue
[ set uev (evalue + ([pvalue] of myself) - pvalue)
  set upv (pvalue + 1)
  ask myself
  [ set cpv (pvalue + 1 )

```

```

        set assigned? true
    ]
]
]
]
]
ask envstwds
[ if (random 100) < chance-env-steward
  [ ask uncooptvs in-radius pradius
    [ if pvalue < [pvalue] of myself
      [ set uev (evalue + ([pvalue] of myself) - pvalue)
        set upv (pvalue + 1)
        ask myself
        [ set epv (pvalue + 1 )
          set assigned? true
        ]
      ]
    ]
  ]
]
]
]
]
];; SWAP TEMP VALUES BACK TO TRUE VALUES
ask uncooptvs
[if assigned?
  [ ask cooptvs in-radius pradius
    [ ifelse cev > [evalue] of myself
      [ set evalue cev
        set cev 0
      ]
      [ set evalue [evalue] of myself
        set cev 0
      ]
    ]
  if pvalue < [pvalue] of myself
    [ set pvalue cpv
      set cpv 0
      ask myself
      [ set pvalue upv
        set upv 0
        set assigned? false
      ]
    ]
  ]
]
]
]
]
ask cooptvs
[if assigned?
  [ ask uncooptvs in-radius pradius
    [ ifelse uev < [evalue] of myself
      [ set evalue uev
        set uev 0
      ]
      [ set evalue [evalue] of myself
        set uev 0
      ]
    ]
  if pvalue < [pvalue] of myself
    [ set pvalue upv
      set upv 0
    ]
  ]
]
]
]
]

```

```

    ask myself
      [ set pvalue cpv
        set cpv 0
        set assigned? false
      ]
    ]
  ]
]
]
ask envstws
[if assigned?
  [ ask uncooptvs in-radius pradius
    [ ifelse uev < [evaluate] of myself
      [ set evaluate uev
        set uev 0
      ]
    [ set evaluate [evaluate] of myself
      set uev 0
    ]
  ]
  if pvalue < [pvalue] of myself
    [ set pvalue upv
      set upv 0
      ask myself
        [ set pvalue epv
          set epv 0
          set assigned? false
        ]
    ]
  ]
]
]
]
ask envstws
[if assigned?
  [ ask cooptvs in-radius pradius
    [ ifelse cev < [evaluate] of myself
      [ set evaluate cev
        set cev 0
      ]
    [ set evaluate [evaluate] of myself
      set cev 0
    ]
  ]
  if pvalue < [pvalue] of myself
    [ set pvalue cpv
      set cpv 0
      ask myself
        [ set pvalue epv
          set epv 0
          set assigned? false
        ]
    ]
  ]
]
]
]
]
end

```

```

;;; DUMP: AVG DAILY TRASH/PERSON ON NN IS EST. 4lbs
;;; NATIONAL AVG. IS 4.43 lbs/PERSON
;;; MODEL BASED ON HOUSEHOLDS WITH 3.39 PEOPLE/HOUSE
;;; HOUCK TIPPING FEE IS $1.00 / BAG (avg bag weight = 10lbs )
;;; REPORTED IN TONS (lbs / 2000)

to dump
  if dump?
    [ if ticks mod dump-once-per = 0 ; ticks mod = 0 is setting for true
      [
        ifelse economics?
          ;;; economics drives decision where to dump but evaluate is influenced by net$ result that could influence
          ;;; decision next time
            [ ask uncooptvs
              [
                let id-fuelcost? (( truck-fuel * distance-id / miles/gal ) * 2 )
                ;;; 1 patch is estimated at 2692 sq ft (48.48 x 55.53) not always certain of the path so split the distance to be
                ;;; 52 ft traveled across a patch center to center (48.48 + 55.53 / 2) set to miles
                set distance-cp distance [ place 1 ] of self * 52 / 5280
                set distance-id distance (min-one-of illegal-ds [ distance myself ] ) * 52 / 5280
                if clean-tech$? = false
                  [
                    set trash-dumped (trash-dmpd/prsn * 3.39) * dump-once-per / 2000
                    set illegal-trash illegal-trash + trash-dumped
                    set dump$ dump$ + id-fuelcost?
                    set mydump$ id-fuelcost?
                    set mynet$id? id-fuelcost? * -1
                    set mynet$ mynet$id?
                    set evaluate evaluate - (.1 * abs mynet$ / 100 )
                    set pvalue pvalue - (.1 * abs mynet$ / 100 )
                    if trash-dmpd/prsn > 0
                      ;;; not to scale, just used as a visual indicator of illegal trash dumping
                      [ ask patches in-radius (trash-dmpd/prsn / 2)
                        [ set pcolor 32
                          set polluted? true
                          set cleaned? false
                        ]
                      ]
                    ]
                  if clean-tech$? and ce-cpn = 0
                    [
                      ;;; model based on head-household taking decision about household trash (3.39*4lbs=13.56lbs/house/day).
                      ;;; Avg. person/household is 3.39 with 319 households max in the area. Divide by 2000 to get tons. Set as
                      ;;; trash per day so x ticks mod to cover # days in mod.
                      let trash-dumped? (trash-dmpd/prsn * 3.39) * dump-once-per / 2000
                      ;;; fuel cost to collection point (cp) x 2 for round trip and -1 to set as negative cost once per ticks mod value
                      let cp-fuelcost? (( truck-fuel * distance-cp / miles/gal ) * 2 )
                      let myrcycl$cpn? ( ( trash-dumped? * rcycl-volume / 100 ) * 2000 * rcycl-value ) * rcycl-cpn / 100
                      ;;; tipping fee is $x/bag. Assume on avg. 20 lb yard bags are used (est. avg 13 gal. kitchen bag weight is
                      ;;; 10lbs.) Trash-dumped reported in tons, x 2000 to get lbs2
                      let mylegaldump$? cp-fuelcost? + ( tipping-fee * trash-dumped? * 2000 / 20 )
                      let myillegaldump$? id-fuelcost? * -1
                      set mynet$cp? myrcycl$cpn? - mylegaldump$?
                      set mynet$id? id-fuelcost? * -1
                    ]
                    ; if it makes economic sense to go to the collection point then do so.
                    ifelse mynet$cp? > mynet$id?

```

```

[ set trash-dumped (trash-dmpd/prsn * 3.39) * dump-once-per / 2000
  set legal-trash legal-trash + trash-dumped
  set recycled-trash recycled-trash + ( trash-dumped * rcycl-volume / 100 )
  set landfill landfill + ( trash-dumped - (trash-dumped * rcycl-volume / 100 ))
;;; Recycle-value is $/lb, need to convert volume back to lbs. 10% of legal trash dumped is est. to be
;;;recyclable. Recycling is marginally more profitable than waste-to-fuels
  set myrcycl$cpn ( ( trash-dumped * rcycl-volume / 100 ) * 2000 * rcycl-value ) * rcycl-cpn / 100
  set dump$ dump$ + cp-fuelcost? + ( tipping-fee * trash-dumped * 2000 / 20 )
  set mydump$ cp-fuelcost? + ( tipping-fee * trash-dumped? * 2000 / 20 )
  set mynet$ mynet$cp?
;;; incentive is higher to begin cleaning up trash to make money
  set evalue evalue + (.25 * abs mynet$ / 100 )
  set pvalue pvalue + (.25 * abs mynet$ / 100 )
]
;;;ELSE
[ set illegal-trash illegal-trash + trash-dumped?
  set dump$ dump$ + id-fuelcost?
  set mydump$ id-fuelcost?
  set mynet$ mynet$id?
  set evalue evalue - (.1 * abs mynet$ / 100 )
  set pvalue pvalue - (.1 * abs mynet$ / 100 )
  if trash-dmpd/prsn > 0
;;; not to scale, just used as a visual indicator of illegal trash dumping
  [ ask patches in-radius (trash-dmpd/prsn / 2)
    [ set pcolor 32
      set polluted? true
      set cleaned? false
    ]
  ]
]
]
if clean-tech$? and ce-cpn > 0
[ let trash-dumped? (trash-dmpd/prsn * 3.39) * dump-once-per / 2000
;;; fuel cost to collection point (cp) x 2 for round trip and -1 to set as negative cost once per ticks mod value
  let cp-fuelcost? (( truck-fuel * distance-cp / miles/gal ) * 2 )
  let myrcycl$cpn? ( ( trash-dumped? * rcycl-volume / 100 ) * 2000 * rcycl-value ) * rcycl-cpn / 100
;;; tipping fee is $x/bag. Assume on avg. 20 lb yard bags are used (est. avg 13 gal. kitchen bag weight is
;;; 10lbs.) Trash-dumped reported in tons, x 2000 to get lbs2
  let mylegaldump$? cp-fuelcost? + ( tipping-fee * trash-dumped? * 2000 / 20 )
  let myillegaldump$? id-fuelcost? * -1
  let mydrywtf-trash ( trash-dumped? - ( trash-dumped? * rcycl-volume / 100 )) * .7765
  set myce-gal mydrywtf-trash * 95.11
  set myce$cpn myce-gal * ce-value * ce-cpn / 100
  set mynet$cp? myrcycl$cpn? + myce$cpn - mylegaldump$?
  set mynet$id? id-fuelcost? * -1
  ifelse mynet$cp? > mynet$id? ;; if economical to go to the collection point then calc.
  [ set trash-dumped (trash-dmpd/prsn * 3.39) * dump-once-per / 2000
    set legal-trash legal-trash + trash-dumped
    set recycled-trash recycled-trash + ( trash-dumped * rcycl-volume / 100 )
    set wtf-trash wtf-trash + ( trash-dumped - ( trash-dumped * rcycl-volume / 100 ))
    set landfill landfill + ( trash-dumped - ((trash-dumped * rcycl-volume / 100 ) + ( trash-dumped
- (trash-dumped * rcycl-volume / 100 )))
    set myrcycl$cpn ( ( trash-dumped * rcycl-volume / 100 ) * 2000 * rcycl-value ) * rcycl-cpn /
100
    set dump$ dump$ + cp-fuelcost? + ( tipping-fee * trash-dumped * 2000 / 20 )
    set mydump$ cp-fuelcost? + ( tipping-fee * trash-dumped? * 2000 / 20 )

```

```

        set mynet$ mynet$cp?
    ;; incentive is higher to begin cleaning up trash to make money
        set evalue evalue + (.25 * abs mynet$ / 100 )
        set pvalue pvalue + (.25 * abs mynet$ / 100 )
    ]
    ;;ELSE
    [ set illegal-trash illegal-trash + trash-dumped?
      set dump$ dump$ + id-fuelcost?
      set mydump$ id-fuelcost?
      set mynet$ mynet$cid?
      set evalue evalue - (.1 * abs mynet$ / 100 )
      set pvalue pvalue - (.1 * abs mynet$ / 100 )
      if trash-dmpd/prsn > 0
    ;; not to scale, just used as a visual indicator of illegal trash dumping
        [ ask patches in-radius (trash-dmpd/prsn / 2)
          [ set pcolor 32
            set polluted? true
            set cleaned? false
          ]
        ]
    ]
    ]
    ]
    ]
    ;; evaluate dictates to dump legally but evaluate is influenced by net$ result that could influence decision
    ;; next time
    ask cooptvs
    [ set trash-dumped (trash-dmpd/prsn * 3.39) * dump-once-per / 2000
      set legal-trash legal-trash + trash-dumped
      if clean-tech$? = false
    [ set landfill landfill + (trash-dmpd/prsn * 3.39) * dump-once-per / 2000 ]
    if clean-tech$? and ce-cpn = 0
    [ set recycled-trash recycled-trash + ( trash-dumped * rcycl-volume / 100 )
      set myrcycl$cpn ( ( trash-dumped * rcycl-volume / 100 ) * 2000 * rcycl-value ) * rcycl-cpn / 100
      set landfill landfill + ( trash-dumped - (trash-dumped * rcycl-volume / 100 ))
    ]
    if clean-tech$? and ce-cpn > 0
    [ set recycled-trash recycled-trash + ( trash-dumped * rcycl-volume / 100 )
      set myrcycl$cpn ( ( trash-dumped * rcycl-volume / 100 ) * 2000 * rcycl-value ) * rcycl-cpn / 100
      set wtf-trash wtf-trash + ( trash-dumped - ( trash-dumped * rcycl-volume / 100 ))
    ]
    ;; straight conversion - no accumulation waste-to-fuels ready trash: less recyclables by 10% and less
    ;; moisture content - set on dry basis, a 22.35% avg. weight reduction, i.e. %factor of .7765
        let mydrywtf-trash ( trash-dumped - ( trash-dumped * rcycl-volume / 100 )) * .7765
    ;;straight conversion no accumulation. 1 ton msw end waste on dry basis yields 95.11 gal. ethanol, i.e. 1 lb
    ;; yields .0475 gal., at ethanol prices of $1.85, 1 lb msw has est. value of 8 cents.
        set myce-gal mydrywtf-trash * 95.11
    ;;ce-cpn variable setting depends on processing profitability not calculated in this model. A conservative
    ;; figure here would be less than 2%.
        set myce$cpn myce-gal * ce-value * ce-cpn / 100
    ]
    ;; 1 patch is estimated at 2692 sq ft (48.48 x 55.53) not always certain of the path so split the distance to be
    ;; 52 ft traveled across a patch center to center (48.48 + 55.53 / 2) set to miles
        set distance-cp distance [ place 1 ] of self * 52 / 5280
        set distance-id distance (min-one-of illegal-ds [ distance myself ] ) * 52 / 5280
    ;; fuel cost to collection point (cp) x 2 for round trip and -1 to set as negative cost once per ticks mod value
        let cp-fuelcost (( truck-fuel * distance-cp / miles/gal ) * 2 )
    ;; fuel cost to illegal trash site (its) x 2 for round trip and -1 to set as negative cost once per ticks mod

```

```

;;; value
    let id-fuelcost (( truck-fuel * distance-id / miles/gal ) * 2 )
    set dump$ dump$ + cp-fuelcost + ( tipping-fee * trash-dumped * 2000 / 20 )

;;; Reported as cost per dump, not cumulative. Tipping fee is $x/bag. Assume on avg. 20 lb yard bags are
;;; used (est. avg 13 gal. kitchen bag weight is 10lbs.) Trash-dumped reported in tons, x 2000 to get lbs
    set mydump$ cp-fuelcost + ( tipping-fee * trash-dumped * 2000 / 20 )
    set mynet$cp myrcycl$cpn + myce$cpn - mydump$
    set mynet$id id-fuelcost * -1
    set mynet$ mynet$cp

;;; An envsteward is not immune to economic influences that will either bolster or erode the value
;;; orientation over time but at a slower rate than others due to the deeper convictions held
    ifelse mynet$cp > mynet$id

;;; positive economics have a greater influence on env stew than negative economics due to conviction of
;;; beliefs
    [ set evalue evalue + (.5 * abs mynet$ / 10 )
      set pvalue pvalue + (.5 * abs mynet$ / 10 )
    ]
    [ set evalue evalue - (.1 * abs mynet$ / 100 )
      set pvalue pvalue - (.1 * abs mynet$ / 100 )
    ]
  ]

;;; evaluate dictates to dump legally but evaluate is influenced by net$ result that could influence decision
;;;next time
  ask envstwds
  [ set trash-dumped (trash-dmpd/prsn * 3.39) * dump-once-per / 2000
    set legal-trash legal-trash + trash-dumped
    if clean-tech? = false
    [ set landfill landfill + (trash-dmpd/prsn * 3.39) * dump-once-per / 2000 ]
    if clean-tech? and ce-cpn = 0
    [ set recycled-trash recycled-trash + ( trash-dumped * rcycl-volume / 100 )
      set myrcycl$cpn ( ( trash-dumped * rcycl-volume / 100 ) * 2000 * rcycl-value ) * rcycl-cpn / 100
      set landfill landfill + ( trash-dumped - (trash-dumped * rcycl-volume / 100 ))
    ]
    if clean-tech? and ce-cpn > 0
    [ set recycled-trash recycled-trash + ( trash-dumped * rcycl-volume / 100 )
      set myrcycl$cpn ( ( trash-dumped * rcycl-volume / 100 ) * 2000 * rcycl-value ) * rcycl-cpn / 100
      set wtf-trash wtf-trash + ( trash-dumped - ( trash-dumped * rcycl-volume / 100 ))
      let mydrywtf-trash ( trash-dumped - ( trash-dumped * rcycl-volume / 100 )) * .7765
      set myce-gal mydrywtf-trash * 95.11
      set myce$cpn myce-gal * ce-value * ce-cpn / 100
    ]
  ]
  set distance-cp distance [ place 1 ] of self * 52 / 5280
  set distance-id distance (min-one-of illegal-ds [ distance myself ] ) * 52 / 5280
;;; fuel cost to collection point (cp) x 2 for round trip and -1 to set as negative cost once per ticks mod value
  let cp-fuelcost (( truck-fuel * distance-cp / miles/gal ) * 2 )
;;; fuel cost to illegal trash site (its) x 2 for round trip and -1 to set as negative cost once per ticks mod value
  let id-fuelcost (( truck-fuel * distance-id / miles/gal ) * 2 )
  set dump$ dump$ + cp-fuelcost + ( tipping-fee * trash-dumped * 2000 / 20 )
  set mydump$ cp-fuelcost + ( tipping-fee * trash-dumped * 2000 / 20 )
  set mynet$cp myrcycl$cpn + myce$cpn - mydump$
  set mynet$id id-fuelcost * -1
  set mynet$ mynet$cp

;;; An envsteward is not immune to economic influences that will either bolster or erode the value
;;; orientation over time but at a slower rate than others due to the deeper convictions held
    ifelse mynet$cp > mynet$id

```

```

    [ set evaluate evaluate + (.5 * abs mynet$ / 10 )
    ;;; positive economics have a greater influence on env stew than negative economics due to conviction of
    ;;; beliefs
        set pvalue pvalue + (.5 * abs mynet$ / 10 )
    ]
    [ set evaluate evaluate - (.01 * abs mynet$ / 100 )
    set pvalue pvalue - (.01 * abs mynet$ / 100 )
    ]
    ]
    ]
    ;;;ELSE WITHOUT ECONOMICS?
    ;;;;; uncooptv makes a one time calculation to evaluate net economic benefit to a single dump decision (i.e.
    ;;; non-cumulative basis). No env. value consideration up front
    [ ask uncooptvs
        [ set trash-dumped (trash-dmpd/prsn * 3.39) * dump-once-per / 2000
        set illegal-trash illegal-trash + trash-dumped
        if trash-dmpd/prsn > 0
    ;;; not to scale, just used as a visual indicator of illegal trash dumping
        [ ask patches in-radius (trash-dmpd/prsn / 3)
            [ set pcolor 32
                set polluted? true
                set cleaned? false
            ]
        ]
    ]
    ask cooptvs
    [ set trash-dumped (trash-dmpd/prsn * 3.39) * dump-once-per / 2000
    set legal-trash legal-trash + trash-dumped
    set landfill landfill + (trash-dmpd/prsn * 3.39) * dump-once-per / 2000
    ]
    ask envstwds
    [ set trash-dumped (trash-dmpd/prsn * 3.39) * dump-once-per / 2000
    set legal-trash legal-trash + trash-dumped
    set landfill landfill + (trash-dmpd/prsn * 3.39) * dump-once-per / 2000
    ]
    ]
    ]
    ]
end

to clean
if clean?
[ if ticks mod clean-once-per = 0
[ ask envstwds
[ ifelse economics?
[ ifelse illegal-trash - ( trash-clnd/prsn / 2000 ) >= 0
[ set trash-cleaned trash-clnd/prsn / 2000
set illegal-trash illegal-trash - trash-cleaned
set legal-trash legal-trash + trash-cleaned
if clean-tech$? = false
[ set landfill landfill + trash-cleaned ] ;(trash-dmpd/prsn * 3.39) * dump-once-per / 2000 ]
if clean-tech$? and ce-cpn = 0
[ set recycled-trash recycled-trash + ( trash-cleaned * rcycl-volume / 100 )
set myrcycl$cpn ( ( trash-cleaned * rcycl-volume / 100 ) * 2000 * rcycl-value ) * rcycl-cpn / 100
set landfill landfill + ( trash-cleaned - (trash-cleaned * rcycl-volume / 100 ))

```



```

]
if clean-tech$? and ce-cpn > 0
[ set recycled-trash recycled-trash + ( trash-cleaned * rcycl-volume / 100 )
  set myrcycl$cpn ( ( trash-cleaned * rcycl-volume / 100 ) * 2000 * rcycl-value ) * rcycl-cpn / 100
  set wtf-trash wtf-trash + ( trash-cleaned - ( trash-cleaned * rcycl-volume / 100 ))
;;; straight conversion - no accumulation waste-to-fuels ready trash: less recyclables by 10% and less
;;;moisture content - set on dry basis, a 22.35% avg. weight reduction, i.e. %factor of .7765
  let mydrywtf-trash ( trash-cleaned - ( trash-cleaned * rcycl-volume / 100 )) * .7765
  ;; straight conversion no accumulation. 1 ton msw end waste on dry basis yields 95.11 gal. ethanol, i.e. 1
  ;; lb yields .0475 gal., at ethanol prices of $1.85, 1 lb msw has est. value of 8 cents.
  set myce-gal mydrywtf-trash * 95.11
  ;; ce-cpn variable setting depends on processing profitability not calculated in this model. A conservative
  ;; figure here would be less than 2%.
  set myce$cpn myce-gal * ce-value * ce-cpn / 100
]
;;; not to scale, just used as a visual indicator of illegal trash cleanup
ask patches in-radius ( trash-clnd/prsn / 2 )
[
  if Landscape = "Base" and cleaned? = false
  [ set cleaned? true
    set polluted? false
    set pcolor base
  ]
  if Landscape = "Roads" and cleaned? = false
  [ set cleaned? true
    set polluted? false
    set pcolor roads
  ]
  if Landscape = "Traveled" and cleaned? = false
  [ set cleaned? true
    set polluted? false
    set pcolor sat
  ]
  if Landscape = "Satellite" and cleaned? = false
  [ set cleaned? true
    set polluted? false
    set pcolor sat
  ]
  if Landscape = "Terrain" and cleaned? = false
  [ set cleaned? true
    set polluted? false
    set pcolor terrain
  ]
]
]
;;; ELSE illegal-trash - trash-clnd/prsn < 0
[ set illegal-trash 0
  set legal-trash legal-trash + (( trash-clnd/prsn / 2000 ) - ( ( trash-clnd/prsn / 2000 ) - illegal-trash ))
  ;;; to set legal trash exactly what is cleaned to prevent going negative
  set trash-cleaned (( trash-clnd/prsn / 2000 ) - ( ( trash-clnd/prsn / 2000 ) - illegal-trash ))
  ;;; not to scale, just used as a visual indicator of illegal trash cleanup
  ask patches in-radius ( trash-clnd/prsn / 2 )
  [
    if Landscape = "Base" and cleaned? = false
    [ set cleaned? true
      set polluted? false
    ]
  ]
]

```

```

    set pcolor base
  ]
  if Landscape = "Roads" and cleaned? = false
  [ set cleaned? true
    set polluted? false
    set pcolor roads
  ]
  if Landscape = "Traveled" and cleaned? = false
  [ set cleaned? true
    set polluted? false
    set pcolor sat
  ]
  if Landscape = "Satellite" and cleaned? = false
  [ set cleaned? true
    set polluted? false
    set pcolor sat
  ]
  if Landscape = "Terrain" and cleaned? = false
  [ set cleaned? true
    set polluted? false
    set pcolor terrain
  ]
]
]
]
];;ELSE-ECONOMICS? = FALSE
[ ifelse illegal-trash - ( trash-clnd/prsn / 2000 ) >= 0
  [ set illegal-trash illegal-trash - ( trash-clnd/prsn / 2000 )
    set legal-trash legal-trash + ( trash-clnd/prsn / 2000 )
    set landfill landfill + ( trash-clnd/prsn / 2000 )
];; not to scale, just used as a visual indicator of illegal trash cleanup
ask patches in-radius ( trash-clnd/prsn / 2 )
[
  if Landscape = "Base" and cleaned? = false
  [ set cleaned? true
    set polluted? false
    set pcolor base
  ]
  if Landscape = "Roads" and cleaned? = false
  [ set cleaned? true
    set polluted? false
    set pcolor roads
  ]
  if Landscape = "Traveled" and cleaned? = false
  [ set cleaned? true
    set polluted? false
    set pcolor sat
  ]
  if Landscape = "Satellite" and cleaned? = false
  [ set cleaned? true
    set polluted? false
    set pcolor sat
  ]
  if Landscape = "Terrain" and cleaned? = false
  [ set cleaned? true

```



```

    ]
    if Landscape = "Traveled" and cleaned? = false
      [ set cleaned? true
        set polluted? false
        set pcolor sat
      ]
    if Landscape = "Satellite" and cleaned? = false
      [ set cleaned? true
        set polluted? false
        set pcolor sat
      ]
    if Landscape = "Terrain" and cleaned? = false
      [ set cleaned? true
        set polluted? false
        set pcolor terrain
      ]
    ]
  ]
]
end

to update-radius
  set eradius ( abs evalue )
  set pradius ( abs pvalue )
end

to adapt
  if evalue >= 3 [ be-env-stew ]
  if evalue >= 0 and evalue < 3 [ be-cooperative ]
  if evalue < 0 [ be-uncooperative ]
end

to be-uncooperative
  set breed uncooptvs
  set color red
end

to be-env-stew
  set breed envstwds
  set color cyan
end

to be-cooperative
  set breed cooptvs
  set color green
end

to update-monitored-variables
  set #envstwds count envstwds
  set #cooptvs count cooptvs
  set #uncooptvs count uncooptvs
  ifelse count envstwds > 0
    [ set %envstwds (count envstwds) / (count envstwds + count cooptvs + count uncooptvs) * 100 ]
    [ set %envstwds "0.00" ]
  ifelse count cooptvs > 0
    [ set %cooptvs (count cooptvs) / (count envstwds + count cooptvs + count uncooptvs) * 100 ]

```

```

[ set %cooptvs "0.00" ]
ifelse count uncooptvs > 0
[ set %uncooptvs (count uncooptvs) / (count envstwds + count cooptvs + count uncooptvs) * 100 ]
[ set %uncooptvs "0.00" ]
;;; to report each patch in acres, 1 patch here is = 2692 sq ft / 43560 sq ft per acre
set #patches-polluted count patches with [ polluted? = true ] * (2692 / 43560)
set %patches-polluted (count patches with [ polluted? = true ]) / (count patches) * 100
;;; to report in acres
set #patches-cleaned count patches with [ polluted? = false ] * (2692 / 43560)
ifelse (count patches with [ polluted? = false ] + count patches with [ polluted? = true ]) > 0
[ set %pollution-cleaned (count patches with [ polluted? = false ]) / (count patches with [ polluted? =
false ] + count patches with [ polluted? = true ]) * 100 ]
[ set %pollution-cleaned "0.00" ]
ifelse count envstwds > 0
[ set avg-EV-env-stew (sum [evalue] of envstwds) / count envstwds ]
[ set avg-EV-env-stew "0.00" ]
ifelse count envstwds > 0
[ set avg-PV-env-stew (sum [pvalue] of envstwds) / count envstwds ]
[ set avg-PV-env-stew "0.00" ]
ifelse count cooptvs > 0
[ set avg-EV-cooperative (sum [evalue] of cooptvs) / count cooptvs ]
[ set avg-EV-cooperative "0.00" ]
ifelse count cooptvs > 0
[ set avg-PV-cooperative (sum [pvalue] of cooptvs) / count cooptvs ]
[ set avg-PV-cooperative "0.00" ]
ifelse count uncooptvs > 0
[ set avg-EV-uncooperative (sum [evalue] of uncooptvs) / count uncooptvs ]
[ set avg-EV-uncooperative "0.00" ]
ifelse count uncooptvs > 0
[ set avg-PV-uncooperative (sum [pvalue] of uncooptvs) / count uncooptvs ]
[ set avg-PV-uncooperative "0.00" ]

ifelse economics?
[
;;;SETUP WASTE STREAM
set total-trash illegal-trash + legal-trash
ifelse total-trash > 0
[ set legal-trash% legal-trash / total-trash * 100
set illegal-trash% illegal-trash / total-trash * 100
]
[ ]
ifelse legal-trash > 0
[ set recycled-trash% recycled-trash / legal-trash * 100
set wtf-trash% wtf-trash / legal-trash * 100
set landfill% landfill / legal-trash * 100
]
[ ]
;;; SET UP CO-OP$
;;; tipping fee is $x/bag. Assume on avg. 20 lb yard bags are used (est. avg 13 gal. kitchen bag weight is
;;; 10lbs.) Trash-dumped reported in tons, x 2000 to get lbs
set tip$fee (tipping-fee * legal-trash * 2000 / 20)
ifelse clean-tech$?
[ set ce-gal wtf-trash * .7765 * 95.11
;;; sets wtf-trash to dry weight basis (22.35%) and converts to gallons at 95.11 gal/T
set ce$ ce-gal * ce-value
set recycled$ recycled-trash * 2000 * rcycl-value

```

```

    ifelse rcycl-cpn > 0
      [ set rcycl$coop recycled$ * ((100 - rcycl-cpn) / 100) ]
;;; Allocates a % to co-ops with the rest being allocated to individuals based on coupon setting
      [ set rcycl$coop recycled$ ]
    ifelse ce-cpn > 0
;;; Allocates a % to co-ops with the rest being allocated to individuals based on coupon setting
      [ set ce$coop ce$ * ((100 - ce-cpn) / 100) ]
      [ set ce$coop ce$ ]
      set coop$ tip$fee + rcycl$coop + ce$coop
    ]
    [ set coop$ tip$fee ]

;;; SETUP AGGREGATE NET$ AND PER CAPITA NET$
      set dump$-pc (sum [mydump$] of envstwds + sum [mydump$] of cooptvs + sum [mydump$] of
uncooptvs) / (count envstwds + count cooptvs + count uncooptvs)
      if clean-tech?
        [ set rcycl$cpn recycled$ * rcycl-cpn / 100
          set rcycl$cpn-pc (sum [myrcycl$cpn] of envstwds + sum [myrcycl$cpn] of cooptvs + sum
[myrcycl$cpn] of uncooptvs) / (count envstwds + count cooptvs + count uncooptvs)
          set ce$cpn ce$ * ce-cpn / 100
        ]
        set ce$cpn-pc (sum [myce$cpn] of envstwds + sum [myce$cpn] of cooptvs + sum [myce$cpn] of
uncooptvs) / (count envstwds + count cooptvs + count uncooptvs)
        set net$ rcycl$cpn + ce$cpn - dump$
        set net$-pc rcycl$cpn-pc + ce$cpn-pc - dump$-pc
      ]
;;; ELSE economics?
    [
      set total-trash illegal-trash + legal-trash
      ifelse total-trash > 0
        [ set legal-trash% legal-trash / total-trash * 100
          set illegal-trash% illegal-trash / total-trash * 100
        ]
        [ ]
      ifelse legal-trash > 0
        [ set recycled-trash% recycled-trash / legal-trash * 100
          set wtf-trash% wtf-trash / legal-trash * 100
          set landfill% landfill / legal-trash * 100
        ]
        [ ]
    ]

    set LI legal-trash + illegal-trash
    set LI% legal-trash% + illegal-trash%
    set LRW landfill + recycled-trash + wtf-trash
    set LRW% landfill% + recycled-trash% + wtf-trash%

end

to update-plot
  set-current-plot "Cooperative Behavior"
  set-current-plot-pen "Cooperatives"
  plot count cooptvs
  set-current-plot-pen "Uncooperatives"
  plot count uncooptvs
  set-current-plot-pen "Env Stewards"

```

```

plot count envstwds
set-current-plot-pen "Total"
plot (count envstwds + count cooptvs + count uncooptvs)
set-current-plot "Land Scape"
set-current-plot-pen "Polluted"
plot count patches with [ pcolor = 32 ]
set-current-plot-pen "Cleaned"
plot count patches with [ polluted? = false ]
set-current-plot "Trash Dumped"
set-current-plot-pen "Illegal"
plot illegal-trash
set-current-plot-pen "Legal"
plot legal-trash
set-current-plot-pen "Total"
plot (legal-trash + illegal-trash)
;;; Reported in 100lb units, the following are % estimates of NN recyclables compared to national averages.
;;; Sources: Recyclenewmexico.com & Jacobson Helgoths Consultants
set-current-plot "Recyclables"
set-current-plot-pen "Total"
plot recycled-trash
;; ; Total 10% to 15% recyclables of total captured trash (legally dumped) of which:
set-current-plot-pen "Paper"
plot recycled-trash * .43          ;;; Paper at 43% (34% national average)
set-current-plot-pen "Plastic"
plot recycled-trash * .14          ;;; Plastic at 14% (12% national average)
set-current-plot-pen "Metal"
plot recycled-trash * .11          ;;; Metal at 11% (8% national average)
set-current-plot-pen "Glass"
plot recycled-trash * .07          ;;; Glass at 7% (5% national average)
set-current-plot-pen "Other"
plot recycled-trash * .25          ;;; Other at 25% consists of wood 8%, textile 4%,
food 7%, yard/bio 2%, other 4%
set-current-plot "Landfill Waste"
plot landfill
end

to output
if output?
[ output-show (word "3/10/12 v9.1 TIER-II Dscvry#2B Economics no CE on SUSTAINABLE") ]
; [ output-show (word "----- Day: " ticks "-----")
; ask envstwds [ output-show (word "Legal Trash: " precision legal-trash 0 );" PVALUE: "
precision pvalue 0 ) ]
; ; output-show "" ;; blank line
; ; ask cooptvs [ output-show (word "EVALUE: " precision evaluate 0 " PVALUE: " precision pvalue
0 ) ]
; ; output-show "" ;; blank line
; ; ask uncooptvs [ output-show (word "EVALUE: " precision evaluate 0 " PVALUE: " precision
pvalue 0 ) ]
; ; output-show "" ;; blank line
; output-show (word "WTF %: " precision wtf-trash% 2 " Land Fill %: " precision landfill% 2 " Recycl
%: " precision recycled-trash% 2 )
; ]
end

to setup-write-output
if write?

```

```

[ let file user-new-file
  if is-string? file
  [if file-exists? file
    [file-delete file]
    file-open file
  ]
]
; write-output
end

to write-output
  if write?
  [
    file-print (word "----- Day: " ticks "-----")
    ask envstwds
    [ file-print (word self ": evaluate: " evaluate " pvalue: " pvalue) ]
    file-print "" ;; blank line
  ]
end

```

```

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;;; Dissertation work through Colorado State University

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CHAPTER 5

CHAPTER 5

CONCLUSION: SYNTHESIZING AN UNDERSTANDING OF *COLLABORATIVE ADAPTIVE CAPACITY BUILDING* WITHIN A RESILIENCE FRAMEWORK

INTRODUCTION

This chapter brings my research full circle to the opening problem stated in Chapter 1 that identified the need to focus on human behavior and action as the primary driver behind environmental degradation (IHDP, 2010). A problem that requires researchers to look at the complexity of social-ecological systems through a new, holistic, and pragmatic lens if balanced and sustainable solutions are to be found (NSF, 2009). The overall aim of this chapter is to address how my research has focused on the confluence of human environment interactions and *collaborative adaptive capacity building* and what can be said about this in a resilience framework.

To address this issue, I present a review of my research methods and results that are then interwoven with the concepts of resiliency, adaptive capacity and sustainability. I then arrive at an understanding of *collaborative adaptive capacity building* within a resilience framework and how the collaborative tri-phase dual-model research approach I have taken has added value to problem-solving an issue in a complex adaptive social-ecological system.

A TRI-PHASE DUAL-MODEL RESEARCH APPROACH

Due to the complexities and nonlinearities in social-ecological systems my research approach sought to explore new avenues by taking a semi-quantitative approach, using qualitative data in a soft systems environment applied through agent-based modeling. A soft systems approach does not have clearly defined objective functions at the outset and in fact may begin with competing notions of what the objectives should be. Collaborative learning takes this soft systems approach in order to meaningfully assess multiple world views in a non-prescriptive manner (Daniels, et al., 2001). Similar sentiments are argued by Smit and Wandel (2006) stating that researchers do not specify a priori determinants of adaptive capacity in the community as these are identified from the community itself through collaborative involvement of stakeholders.

Although there was no formal objective in the sense of what exactly was going to be studied at the outset of my participatory exploration, I did have a framework for the way I intended to move the process forward within which the research focus would begin to incubate. My research plan involved the deployment of three phases using a conceptual and an agent-based model. Each phase was designed to couple with the next. Phase-I and Phase-II took place as field research in the rural community of Burntwater, Arizona of the Houck Chapter on the Navajo Nation. The study was in the form of a participatory exploration as approved by Navajo Nation Human Research Review Board (NNR-10.282) entitled *A Community Participatory Exploration of the Environment, Renewable Energy, Human Capacity Building and Entrepreneurial Solutions as Seen by the Navajo through Photo, Art and Stories*. Phase-I explored the initial steps taken to introduce the project into the area and to establish a baseline-understanding around some key concepts

using qualitative elicitation methods, namely one-on-one interviews, focus groups and group consultations. This was followed with implementing a core component of the collaborative participatory exploration—photovoice and artvoice, and brought to a conclusion with a community-wide gathering for participants to share in the results. The conceptual model *Participatory Social Framework of Action* (PSFA) and its inner-core *Collaborative Adaptive Capacity Building* (CACB) was introduced and used during smaller more frequent community gatherings. Phase-III involved the development of a two-tier agent-based model: *Taking Care of the Land – Human Environment Interactions* (TCL-HEI) that looked at behavior, action, economics and renewable energy in the framework of a *Regional Cooperative Clean-Energy Economy* (RCCEE).

Photovoice and Artvoice

Phase-I involved the use of photovoice and artvoice techniques that established a general understanding and awareness of the exploration and resulted in a community-identified issue of concern—illegal trash dumping. Photovoice and artvoice are media where expressions can engender a sense of pride, self-esteem and ownership among its practitioners while also empowering effective communication of an idea or concept.

Photovoice has been used for some time. Artvoice is a variation of the photovoice technique that I introduced as a way to get more of the community involved through arts and crafts. The Navajo have historically favored arts and crafts and continue to express great talent. Navajo art, especially the weaving, is often referred to as “Handiwork of the Gods” (Locke, 2001a, p. 33). Both these techniques are collaborative by design. As pointed out by Wang and Burris (1997) regarding photovoice but that I also extend to

artvoice, these methods rely on the power of visual images and narratives and sees local people as catalysts of change. They are expected to enable participants to record community strengths, weaknesses and concerns; to promote critical dialogue about community issues; to communicate perceptions and knowledge and to reach policy makers. The narrative aspect enables people to reach back into their collective and individual histories to gather knowledge and understanding. It is a method that gives voice to local people (Friere, 1970). Photography can be used as part of analysis in several ways including a reflexive mode where people respond to pictures of their environments (Harper, 1989) and I would say this holds true for art expressions as well.

Through the combination of photovoice, artvoice and consultation group engagements, community members found new avenues of communication and ways of expressing their ideas, emotions and opinions (positive and negative) about their local community that opened up new ways of learning and knowledge sharing. In addition to identifying a common community concern to be addressed, this dual method served a vital purpose in initiating the beginnings of collaboration around a focused engagement to draw in participants, to allow for individual expressions of community issues through these media and for oral expressions in community gatherings in the form of stories and narratives.

Conceptual Model: *Participatory Social Framework of Action – Collaborative Adaptive Capacity Building*

Phase-II formally introduced the model framework called *Participatory Social Framework of Action – Collaborative Adaptive Capacity Building* (PSFA-CACB) (Fig. 5.1) that was introduced to the participants as a conceptual model to help foster the

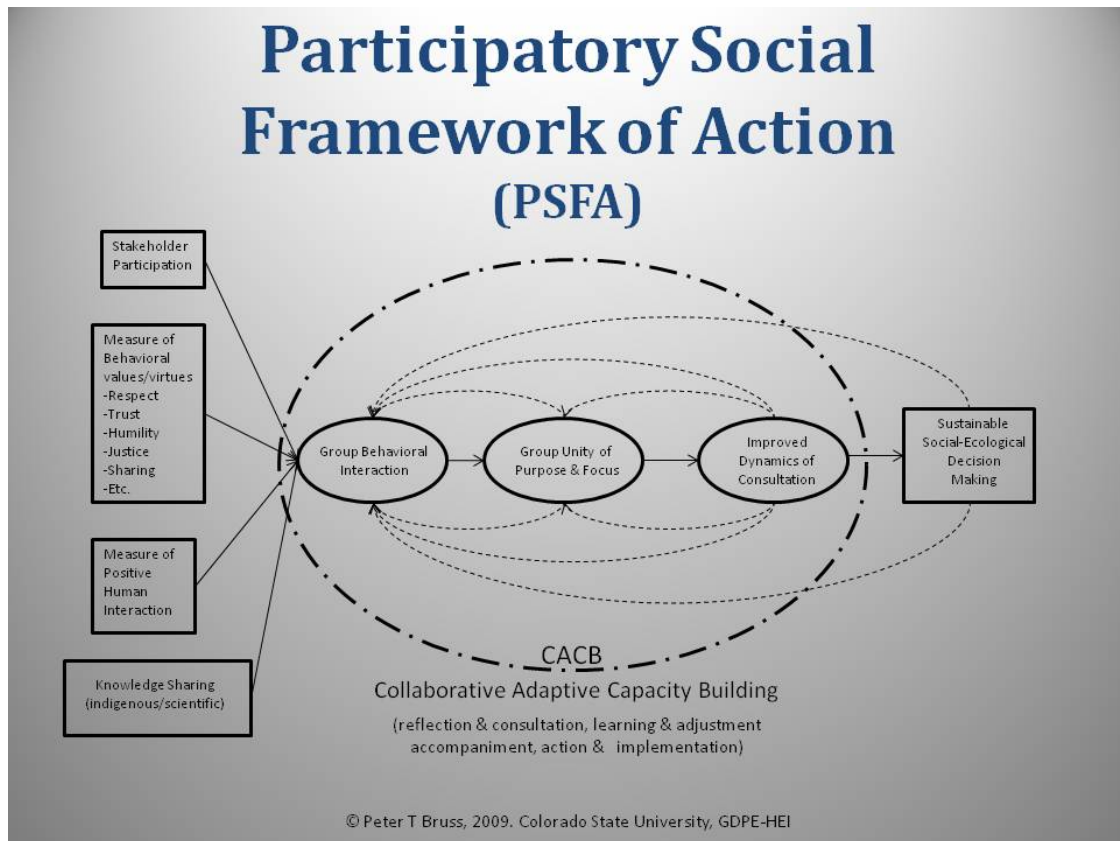


Fig. 5.1 PSFA-CACB Model

collaborative adaptive capacity building process during exploration and discovery.

Conceptually, the PSFA-CACB model attempts to depict interacting forces of human nature that when engaged in a positive environment and with iterative applications of the CACB core (what I call the CACB crucible) I believe will eventually lead to a

favorable outcome towards achieving sustainable decision making and a strengthening in individual and group capacity.

A key component to the PSFA-CACB model is the feedback loops. As the collaborative process steps forward in time there is a need for continuous open and free consultation where feedback on issues, concerns or actions go back to be reworked and reworked until the process can begin to move forward again in a positive direction. Central to this CACB process are iterative cycles of reflection, consultation, action, accompaniment, learning and adjustment (Fig. 5.2). These iterative cycles can occur at

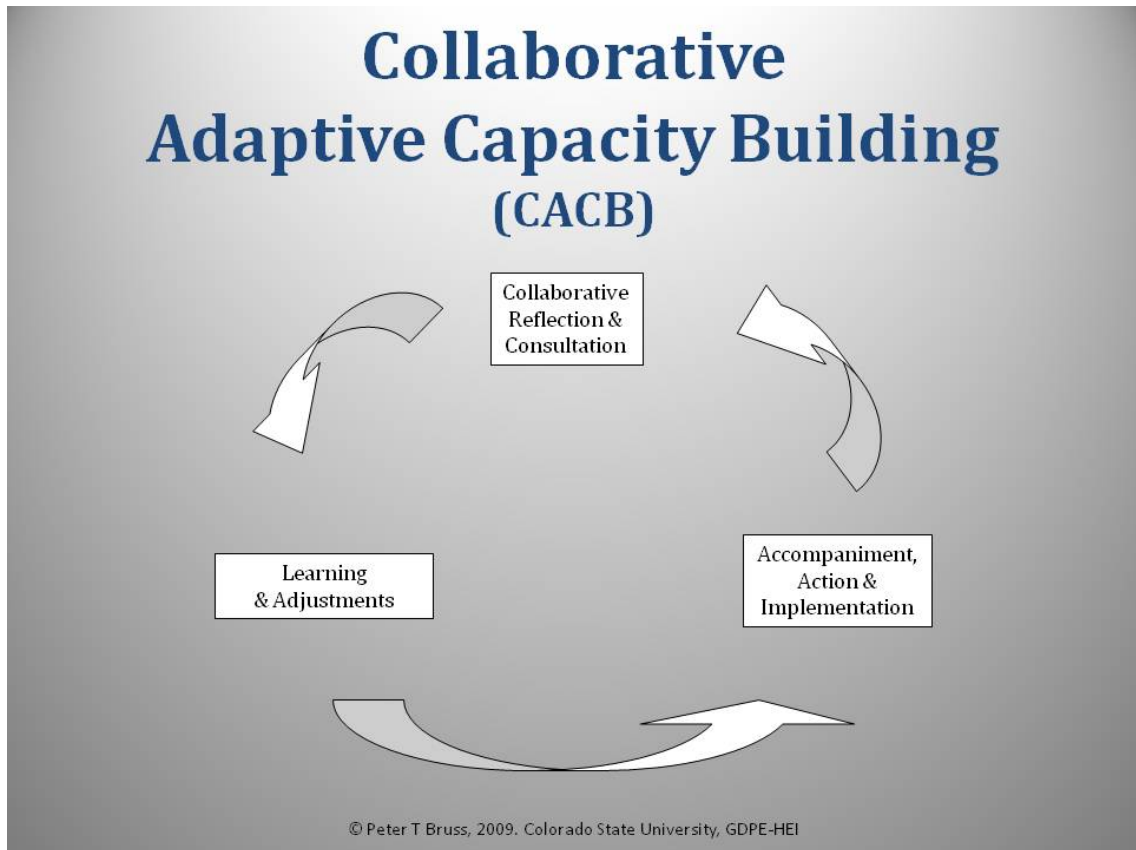


Fig. 5.2 *Collaborative Adaptive Capacity Building (CACB)*

multiple scales, spread out over time, space and levels as participants interact. This may at times be the whole system interacting together or smaller groups of a few or even one-

on-one interactions. What is key is that the process is iterative so that within a humble posture of learning and accompanying one another, adjustments are made as deemed necessary to move forward with action and implementation and then through a consultative/reflective engagement new learnings and adjustments come about and so forth.

Using a three-phased approach to my research was logistically perhaps the best way to proceed as it split the fieldwork into three distinct and manageable phases supported in action by the CACB concept and that were easily identifiable by the participants (Fig. 5.3).

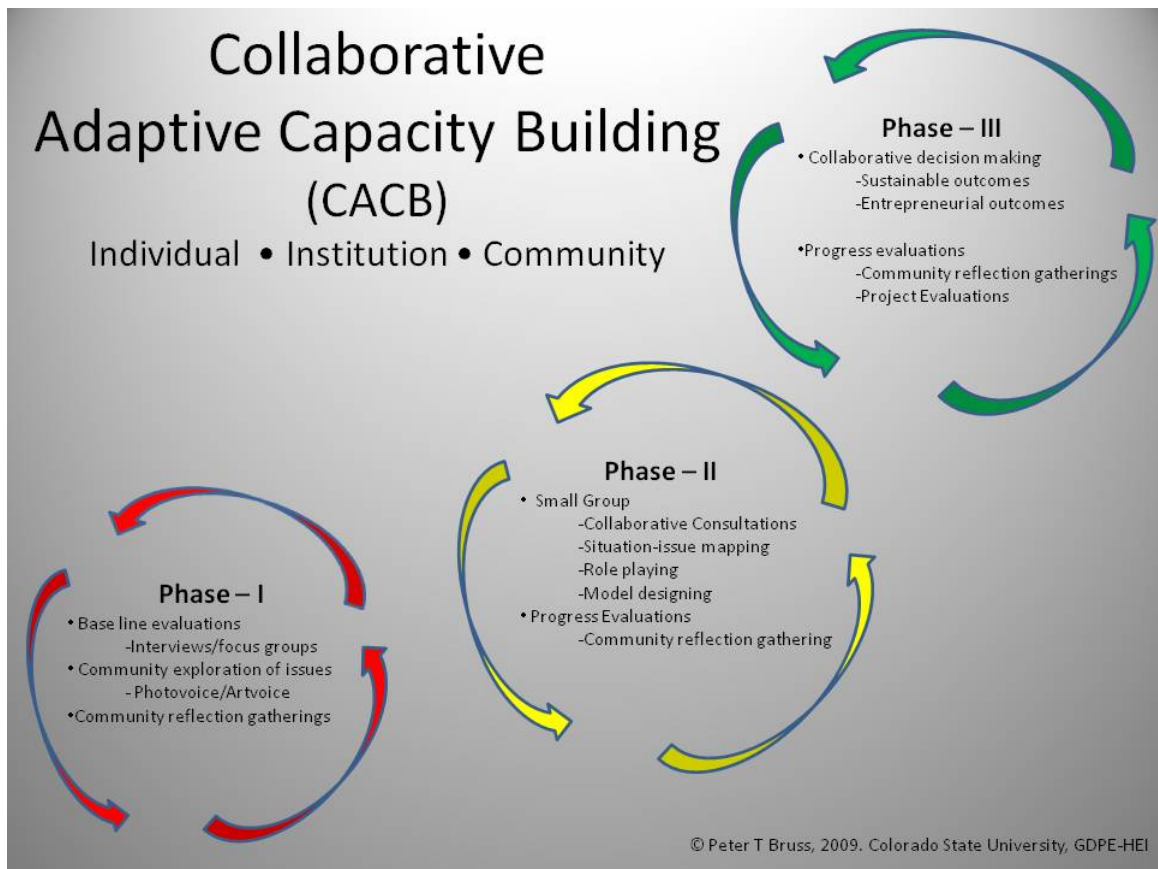


Fig. 5.3 Tri-Phase Application of CACB

As noted in Chapter 3, the general notion of this type of reflexive and iterative interaction is not novel and can perhaps be traced back to components of participatory action research (Whyte, 1991). Further, there is strong evidence of this approach in the works of FUNDAEC (F. Arbab, et al., 1988; H. Arbab, 2000) and that has been increasingly used and refined in Baha'i communities around the world (see Chapter 3). However, what is perhaps novel in my use of this iterative cycle of action, reflection and learning is the unique placement of this approach within a broader conceptual model (PSFA) to make up the PSFA-CACB model and its application in a tri-phase dual-model collaborative field exploration using photovoice and artvoice.

Agent-based Model: *Taking Care of the Land – Human Environment Interactions*

“Art is a lie that helps us see the truth” – Picasso

“All models are wrong but some are useful” – George Box

(Epstein, 2008)

A key feature of agent-based modeling is that it deals with system complexity and enables the modeler to explore this complexity in nonlinear ways resulting in outcomes that could not have been seen just through an analysis of the individual agents themselves. Instead, it is the autonomous interaction of the agents operating within simple heuristic rules under certain assumptions and towards a given objective in their given environment that may give rise to unexpected outcomes—in other words, the whole is greater than the sum of the parts. Emphasis is on the *agents* and not on statistical

variables and this approach is in general alignment with social theory (E. Smith, et al., 2007; Tubara, et al., 2010).

Van den Belt (2004) also explains that simulation modeling, being born out of system dynamics, provides a way to study system change and behavior through an identification of basic building blocks that help to explain core behaviors and where feedback loops and time lags help to identify and characterize the intricate relationships between a system's foundational building blocks. The modeling of these systems helps us to systematically understand these complexities and uncertainties involving time lags, feedbacks and nonlinearities (van den Belt, 2004, p. 3). In altering time lags and scale parameters through the modeling process, policy makers can better overcome the disconnects of time and space. This can be achieved through collapsing scale parameters that will enable them to explore consequences of actions that would normally take place over long time periods and which may not be in sync with institutional structures (Costanza, et al., 2001; van den Belt, 2004). Grimm and Railsback (2005, p. 22) state the purpose of ABM is “to solve problems or answer questions ... a model may address a scientific problem, a management problem, or just a decision in everyday life... to solving real-world problems, simplified models are the only alternative to blind trial and error ...”. It is this *simplification* aspect that Epstein (2008, p. 4) addresses in terms of the need to “illuminate core dynamics” and that modeling although incomplete, over simplifying and altogether wrong, can offer “fertile idealization”, i.e. usefulness.

Phase-III focused on using the data gathered from Phase I and Phase II to inform a two-tiered agent-based simulation model *Taking Care of the Land – Human Environment Interactions* (TCL-HEI). Tier-I of TCL-HEI, focuses on cooperative

behavior, capacity building and decision making dynamics. Tier-II of TCL-HEI is theoretical and looks at aspects of a *Regional Cooperative Clean-Energy Economy* (RCCE). It depicts a hypothetical recycling and clean-technology waste-to-fuels program. With both tiers combined, the agent-based model is semi-hypothetical and can be used to evaluate theoretical implications that a clean-technology recycling and waste-to-fuels program might have on the local environment.

LEARNINGS AND IMPLICATIONS: AN UNDERSTANDING OF *COLLABORATIVE ADAPTIVE CAPACITY BUILDING* WITHIN A RESILIENCE FRAMEWORK

To structure how the learnings from my research are synthesized into a discussion and understanding of *collaborative adaptive capacity building* within a resilience framework, the remaining two research questions are re-presented here.

Q4 - How has *collaborative adaptive capacity building* as a participatory process using photovoice and artvoice brought about positive change through sustainable social action and how is this in turn building resilience to withstand disturbance and overcome vulnerability through collective cooperation and unity in action?

Q5 – How has this tri-phase dual-model (PSFA-CACB conceptual model; TCL-HEI agent-based model) collaborative research added value to problem solving in complex adaptive social-ecological systems?

Given that my research process was an integration of three phases, each phase relying on results from the previous phase, these research questions are linked and overlap. Research question #4 is focused on the research process and results of Phase-I and Phase-II (Chapter 3) while research question #5 focuses at a scale that takes in the entire process and results, including Phase-III (Chapter 4). In addressing these research

questions and the overall theme of understanding *collaborative adaptive capacity building* within a resilience framework, I revisit some relevant resiliency concepts (see Chapter 2 for further discussion) in relation to my research.

Complex Adaptive Social-Ecological Systems

Ecosystems that are both complex and adaptive were traditionally viewed and studied through a systems theory lens (Bertalanffy, 1968) that saw the natural world as an intricate web of stocks and flows regulated by feedback processes. However, adaptation was initially overlooked. This was eventually modified with the understanding that ecosystems and their organisms have an adaptive capacity, i.e., they adapt to change in their environment. From this new perspective an extension to systems theory emerged called complex adaptive systems (CAS) theory that looks at variation and change to system-level responses (Hartvigsen et al., 1988). By adding a layer of complexity to the ecosystem, that of humans and their social reality, the overall system becomes a complex adaptive social-ecological system. Complex adaptive systems such as a social-ecological system involve a great number of simultaneous interacting sub-systems and parts that evolve, manifest aggregate behavior, have the ability to anticipate and adapt, and possess no single governing rule (Holland, 1992). The social-ecological system is in essence the confluence of *social reality* and *physical reality* where social reality pertains to that which is fabricated and conceptualized by humanity (*Homo Faber* – man the creator) in comparison to physical reality that constitutes the natural geo-bio-chemical world. It is through this construction of social reality built upon an objective physical reality that

itself is understood through critical external realism that I can know my research and discovery is not relativistic (Lample, 2009).

Another important theme introduced in Chapter 2 regarding social-ecological systems pertains to how such systems are perceived. Are they to be viewed through a micro or macro lens? In taking a holistic approach, both perspectives would need to come into view. Historically, this is an area where traditional Native American perspectives with a more macro and holistic scope clashed with the Western European reductionist approach to science that in turn influenced the social reality of the day through laws, economics and politics. Western science is beginning to understand that problem solving complex social-ecological systems must allow for an integrated approach and I would argue, who better to involve than the Native Americans who have been marginalized predominantly by a society that operates and runs from a Western European perspective. The Native Americans through their traditional ways and knowledge are increasingly making a significant contribution to a holistic discourse on addressing the plight of our planet's social-ecological systems.

My research field site is on the Colorado Plateau of Northern Arizona and part of the Navajo Nation. It is part of a fragile social-ecological system where change in the natural environment is driven primarily by prevailing weather patterns that consist of two seasonal moisture trajectories: summer convection storms from the Gulf of Mexico and winter storms from Gulf of Alaska. These patterns create a climate boundary that is prone to shifting over long periods of time influencing vegetation growth patterns (Schwinning, et al., 2008). These shifting patterns in biodiversity are not only impacted by climatic drivers but also by human activity introducing invasive species, practicing range land

grazing and the use of vehicles; all of which have been shown to severely impact the biological soil crust comprised of cyanobacteria, micro fungi, lichens, and mosses known as BSC. The BSCs on the Colorado Plateau represent nearly 70% of the living landscape cover driving ecosystem functions and C and N cycles (Belnap, 1995; Schwinning, et al., 2008). Perhaps more importantly, due to persistent drought conditions, BSC play a critical role in soil fertility and ecosystem health through soil particle cohesion and influencing the sizing of soil aggregates that in turn influence soil aeration, porosity, erosion, and moisture retention and infiltration (Belnap, et al., 1993; George, et al., 2003; Schwinning, et al., 2008; Warren, 2003). My research focused on a specific aspect impacting this social-ecological system—human behavior and illegal trash dumping and the interaction of the two with an emphasis on human interaction within an area less than 40 acres.

In a resilience framework and systems science context the state variables defining the specific area of my research within the overall social-ecological system were discussed in Chapter 4 in the ODD sections of the *Taking Care of the Land – Human Environment Interactions* (TCL-HEI) agent-based model. These included system features like people, roads, trash, trash sites, places, collection points and transportation fuel all of which impacted the system one way or another. The particular combination of these state variables is what defines the system and the regime it is in. Based on feedback from my study the system can be said to be in an *undesirable regime domain* (R. Alliance, 2007; Scheffer et al., 2003). In a social context, regime desirability or undesirability is subjective and based on values and a system can exist in multiple alternate system configurations of varying degrees of desirability, as it is all dependent on the observer.

Within the context of my TCL-HEI agent-based model as depicted in a sample view window (Fig. 5.4) it could be said that the regime to everyone, given the poor economics, was undesirable and this was further exacerbated by the state of affairs with undesirable behavior of illegal trash dumping. However, the *uncooperative* agents (red) could be said to have found their niche in this undesirable state of affairs through their illegal action of dumping trash to avoid the undesirable consequences of higher dumping costs (fuel and

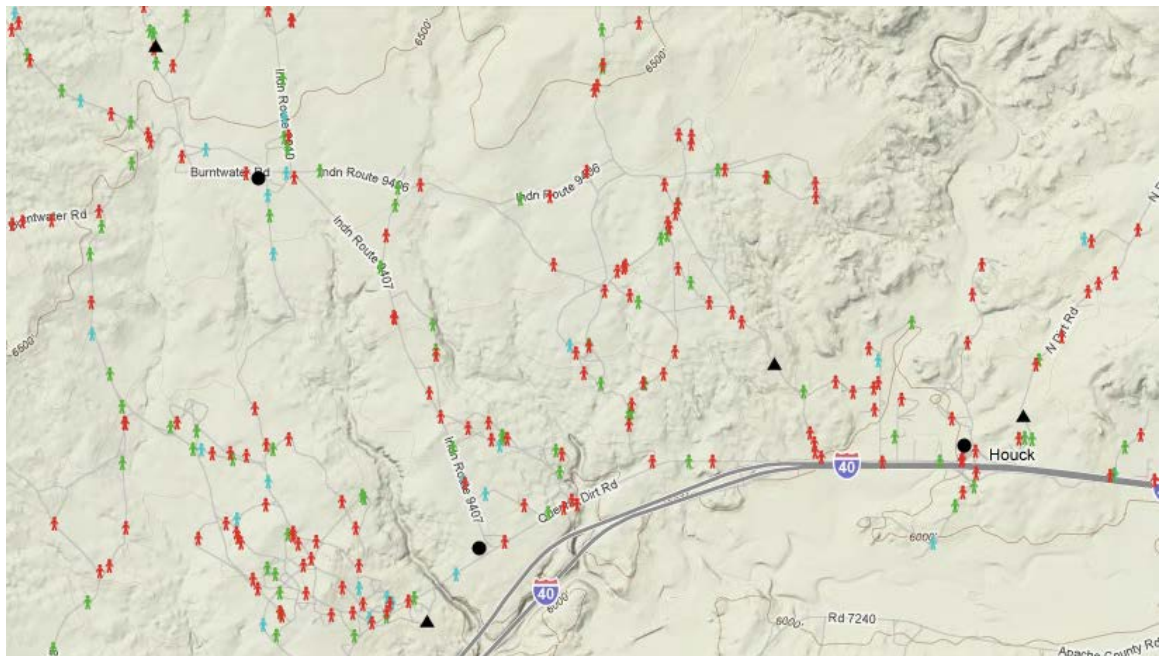


Fig. 5.4 TCL-HEI Agent-based Model View

tipping fees). This would be in contrast to the *environmental steward* (turquoise) and *cooperative* (green) agents who would not take such illegal action except as a last resort. In this undesirable state of affairs, the economic environment that is driving the degradation of the natural environment defines the regime's basin of attraction. As the external shocks hit the system and the stability landscape such as a rise in oil prices or a drop in tourism revenue, the overall state of economic affairs worsens, and more and

more people are driven to dumping trash illegally until eventually the entire system collapses in on itself. A system that can no longer retain its former functionality and purpose is one that lacks resilience and transforms into a different system. A system's state is defined by the values of variables that make up that system. In the case of my research the variables are all those that are being used in the TCL-HEI agent-based model. As the social and physical landscape changes, i.e., a social-ecological system's biophysical and social attributes, the positions of the regime basins alter, getting smaller or larger or disappearing and reappearing. It is the disturbance to the configuration of the system state and corresponding variables that ultimately changes the relative position in which a system finds itself. A system can exist in multiple alternate system configurations depending on the perspective of the observer. Fig. 5.5 depicts a theoretical landscape of alternate states where a system finds itself on that landscape. The red dot

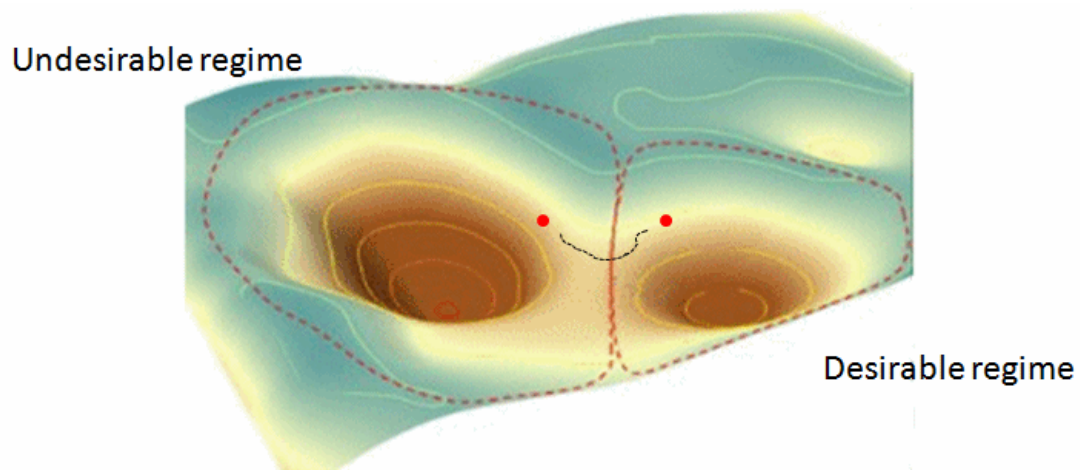


Fig. 5.5 Regime Basin Shift

represents a system's position within the regime basin that is defined by thresholds (contours) that are controlling variables that define and make up that particular basin in which the system finds itself. One has to think of this as a dynamic system where the

stability of the landscape changes based on changes in regime variables. In this context, resilience can be understood as a system's capacity to absorb disturbance and reorganize during change in a way that it can retain the same function, structure, identity, and feedbacks (R. Alliance, 2007; C.S. Holling, 1973; Walker, et al., 2004). If there is resilience in the system, it will find its way back to its original state intact. If key variables in a systems stability landscape were to significantly shift, say from a disturbance, then the system could find itself in an entirely new regime basin of attractors, positive or negative, depending on where the system was and what type of disturbance was impacting the variables and in what direction. In such a case, the system overcomes thresholds and reaches tipping points during the stability landscape shifts. If the system survives the shift, intact as described above, then the system can be said to have resilience. In the context of my research, resilience at the outset is not a good thing as the community is trying to alter the state variables in such a way and to a significant enough magnitude to cause the emergence of a new alternate stability state. They are trying to change their social reality from an undesirable state of affairs of excessive illegal trash dumping to one that is more desirable with less or no illegal trash dumping.

Theoretically, this type of shifting could repeat itself over and over again as variables shift within a system's stability landscape as shown above in Discovery Trial #2B when connectedness through collaboration began to take hold and people began to reorganize their state of affairs through a business cooperative. Economic, social and human capital was deployed to create a new social reality that impacted changed for the better the physical reality. This type of adaptive cycling was first depicted by C.S. Holling (see for example C.S. Holling, 1973; C.S. Holling et al., 2002) where re-

organization and renewal take place during times when a system is tenuous as depicted by alpha (α) in Fig. 5.6. During this alpha period there is potential and energy and new possibilities open up for growth and exploitation (r) but then the system over time begins

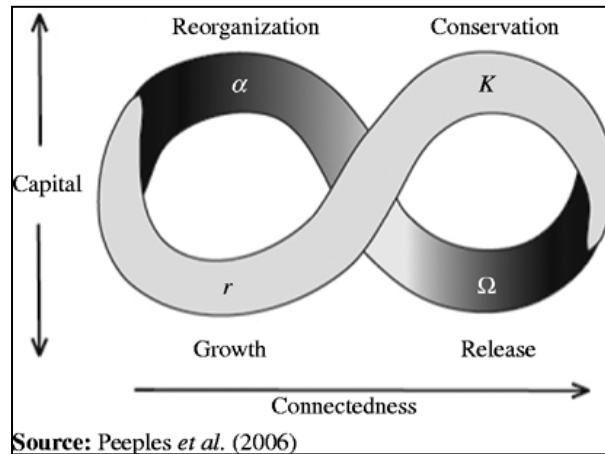


Fig. 5.6 The Adaptive Cycle

to aggregate and stiffen as capital is pooled into fewer and fewer areas of focus and special interest. Depending on the system dynamics, this built up potential could continue on over time with resources remaining locked up (K) and then get released into a period of change when resources are suddenly released (Ω) or the system could go into a rapid release phase from r to Ω . Further discussion as to the application of this theory to my research is shared below.

Sustainable Action and Resilience Building

Central to my research was seeing how change and adaptation might occur through an increased awareness of an issue at the individual and collective level and if this change would be sustainable. Within the context of a resilience framework, the ultimate outcome of the PSFA-CACB model as discussed above is to attain sustainable

decision-making. However, implicit to being able to do this is the need to work collaboratively with others and being able to adapt to change as a means to building individual capacity that in turn strengthens the collective capacity of a community through unity in action. This strengthening of community bonds and relationships through a gradual building of capacity also builds positive resilience to overcome the negative forces and resistance that hold a system in its current regime basin as discussed above. The positive forces that are built up enhance adaptive capacity that enhances the ability for a system to withstand disturbance (R. Alliance, 2007) and hence increase resiliency.

Sustainability is not really a measurable goal in the short-term but there are ways to know if progress is being made. Four broad areas that can be indicators of change towards a more sustainable process include “direction, energy, distributed leadership and appropriate mobilization of resources” (Holman, et al., 2007, p. 60). I believe these measures were well achieved as evidenced by the gradual but growing participation and enthusiasm during Phase-I and Phase-II as well as the emergence of leadership, external community interest and awareness from local, regional and Navajo Nation officials and dignitaries as well as the media including newspaper and radio.

The initial process to bring light to a central issue was through the application of photovoice and artvoice as part of an overall conceptual model *Collaborative Adaptive Capacity Building (CACB)*. My findings from this Phase-I activity were that in addition to identifying a common community concern to be addressed, that of illegal trash dumping, this dual method served a vital purpose in initiating the beginnings of collaboration around a focused engagement. Participants were encouraged and

empowered to express creatively community issues and to offer oral expressions in community gatherings in the form of stories and narratives. Despite severe winter weather that would have normally keep most Navajo at home, Phase-I culminated in a successful well-attended community gathering of photo and art sharing, storytelling, feasting, a gift exchange and a raffle for first, second and third place awards. There was an apparent and real sense of joy, love and unity that was exhibited by all the participants.

The successful conclusion of Phase-I, where a community theme had been born and adopted with full support and collaboration, enabled a natural and seamless launch into Phase-II. It was in Phase-II that the participants gathered on a regular basis to explore specifics behind the issue of illegal trash dumping through an application of the iterative *collaborative adaptive capacity building* process model within the context of the PSFA-CACB model.

The collaborative consultations that occurred during this study have been enriched with the elevated demeanor, patience and wisdom of the Navajo, which I have not typically seen in other western settings. This was experienced in part through the informal Thursday collaborative gatherings and conversations integrated with a local community initiative revolving around a Prayer Hogan gathering and a community dinner sponsored by The Native American Baha'i Institute (NABI, 2012) that has been in the area for many decades. These consultation gatherings have been all inclusive with an open door policy encouraging involvement, action and accompaniment in the exploration/research process. Further underlying the success of the collaborative-consultation outcomes in the NABI environment is the way in which individuals have interacted with each other showing a great degree of patience, humility, and respect. As

Phase-II evolved there was direct evidence of sustainable progress through observable continual engagement due to weekly Thursday meetings organized by the volunteer participants themselves. These meetings were followed by a community dinner offered through NABI. This continual engagement process supported by a local institution has been a vital component in capacity building. Reid et al. (2009) through applications of a continual engagement model showed how progress achieved by the protracted project could build capacity at the individual and institutional levels by engaging participants and integrative processes at multiple levels; noting that the researchers themselves built capacity as well during the process, as was the case in this study. Further to the Reid et al. (2009) example there are already opportunities for boundary spanning resulting from this study as the participants reach out to local civic and business interests and accompany as co-presenters in conference presentations. In the process of doing this, learnings occurred and adaptations were made not only by the participants but by me as the researcher as well, i.e., we were all engaged in building capacity and adapting—a process of *collaborative adaptive capacity building*.

In the context of a resilience framework, a social-ecological system can exhibit both positive and negative feedback. A positive feedback loop occurs “when the output of a process influences the input of the same process in a way that amplifies the process, often in a destabilizing manner” while a negative feedback loop occurs “when the output of a process that influences the input of the same process has a dampening or stabilizing effect, pushing the system towards an equilibrium” (Resilience Alliance, 2002; Bennett, et al., 2005). This can be applied to the PSFA-CACB model where negative output along the continuum is cycled back to former stages and will continue this cycling until

sufficient progress is made to move forward. In other words, the system remains in an equilibrium loop. However, sufficient positive outcome at any given stage will amplify the process forward towards the objective. In the context of this model, therefore, the goal is to move forward and not remain in a state of equilibrium.

The theoretical concept is that as progress is made through these iterative stages, individual and ultimately community capacity is strengthened and knowledge is discovered, shared and in some cases may be generated that empowers the group decision making process to make more sustainable decisions. The cumulative effect of this leads to greater adaptive capacity within the community and ultimately greater resilience by the whole system to withstand endogenous or exogenous shocks and disturbances. When carried out in a constructive atmosphere conducive to growth, these nested and interconnected cycles can be a contagious source of upliftment, engagement, empowerment and capacity building. This is a framework of limitless possibilities based on human dynamics, creativity and interaction. It is dependent, however, on a positive flow of energy that is generated and co-generated through cyclic interactions between people. Such an energy exchange is known to be contagious (Holman, et al., 2007, p. 7).

As the adaptive capacity of the individual participants in the community grows so will the level of positive change increase. This in turn leads to an increase in individual and collective action and again further change. In turn, it is through these changes that the adaptive capacity of the community is improving that is having a positive impact on the social-ecological system all around and perhaps helping to bring it out of its undesirable state, its regime basin, into a desirable regime basin.

A key part of the overall PSFA-CACB approach was building the agent-based models and this was a semi-collaborative process starting with data gathering and game playing during Phases I & II. Collaboration and model building can be complimentary. A particular method of model building is mediated modeling that is “based on system dynamics thinking but emphasizes the interactive involvement of affected stakeholders in the learning process about the complex system they are in. It allows a group of stakeholders to understand how seemingly small decisions may spiral a system onto an undesirable course. Such understanding provides opportunities to jointly design strategies to abate the negative spiral or to curb a trend into a more positive one” (van den Belt, 2004, p. 3). Inherent in its design, mediated modeling aims for a collaborative team learning experience that elevates the shared level of understanding in a group and fosters a broad and deep level of consensus. Mediated modeling helps to structure a group’s thinking and discussion, stimulates joint learning among a group of individuals with varying backgrounds, all of which lead to a new way of learning and building knowledge (van den Belt, 2004, p. 11). Furthermore, simulation modeling can be a means for capacity building. Van den Belt (2004, p. 3) states, “Models offer us the ability to expand our mental capacity in ways that enable us better to understand ecosystems and the implications of our many small management and policy decisions as they relate to ecosystem and human health.” I would argue that these in fact extend beyond just reasons to model. They are outcomes and results of modeling as well and in the context of my research, working towards the goal of developing a model, i.e., the field work of Phase-I and Phase-II, was an effective means for capacity building, collaboration and raising the level of awareness of critical linkages between the environment and humans.

The creation and sharing of the ABM *Taking Care of the Land – Human Environment Interactions* (TCL-HEI) has led to an additional collaborative element in the overall tri-phase approach to exploring *collaborative adaptive capacity building*. With one-on-one feedback from participants, it has inspired and even awed some of the Navajo and I am hoping that the model will serve a purpose as a tool for local and regional Navajo Nation officials further to explore the issues behind illegal trash dumping.

PSFA-CACB / TCL-HEI: Contribution to Solving a Social-Ecological System Problem

The field applications of the PSFA-CACB conceptual model during Phase-I and Phase-II were instrumental in providing both empirical and theoretical knowledge to help build the TCL-HEI agent-based model in Phase-III. It is my conclusion that the utility of both models, executed through a tri-phase plan in the field, has brought about a level of increased awareness to a real social issue impacting the environment. In other words, the social-ecological system at the local scale underwent positive change through social action resulting in a mitigation of environmental degradation. That then led to the development of an agent-based model to depict these changes and impacts, which in turn led to an extended theoretical version of the model to explore the possibility of a sustainable entrepreneurial solution involving a business cooperative opportunity engaged in solid waste recycling and waste-to-fuels processing to generate clean-energy (ethanol).

This overall approach and method has shown signs of adding value to the local community through its hands on practicality, ability to build skill, confidence and learning and overall capacity building. There have even been visible signs that the process is moving in a sustainable direction through self-directed local leadership and drive. The individual and collective capacity of the participants has been raised to identify and resolve issues through this collaborative social research tri-phase / dual-model method. It is my conclusion that if the community were to continue along this path with the continued support of a local institution such as NABI, the long-term effect would be an increase in resiliency enabling it to withstand disturbance and allowing a materially impoverished community gradually to overcome the vulnerability of poverty and wealth deprivation. It can be a means for a community to unite and galvanize differences into unified action towards sustainable entrepreneurial goals that mitigate environmental degradation.

The course of action therefore during the exploration and research took place over three phases and a collaborative application of a conceptual model and an agent-based model resulting in a social-ecological community issue being identified. This was the first positive step towards a possible regime change. The issue was worked over during phase-II resulting in a short-term solution, that of community action to clean up the environment—another positive step towards a regime change or in other words, towards changing its social reality. Finally, a theoretical long-term sustainable entrepreneurial solution was explored through Tier-II of the agent-based model TCL-HEI that looked at turning trash into revenue and clean-energy involving waste-to-fuels processing and recycling. For such a vision to take hold on a sustainable basis, it will require the will of

the greater community at all scales to overcome the negative resilient forces holding the social-ecological system in its current state of affairs.

Theoretically, the model depicted a scenario that suggested if a sufficiently large change could be applied to the existing state of affairs, particularly the state variables of economics as applied at the local and regional scale, then perhaps the system configuration of state variables would be sufficient to cause a regime basin shift placing the system in a more desirable state. The Discovery Trial #2B (Chapter 4) was a theoretical pro-forma case study depicting how this could happen. As the trial run started out the social-ecological system was in a desirable state, where cooperatives on the landscape dominated the behavior and actions of legal trash dumping but this was rapidly shifting as economic dynamics changed (Fig. 5.7).

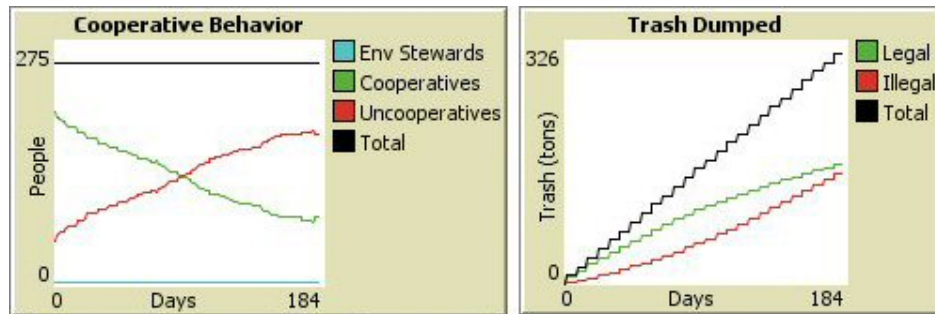


Fig. 5.7 TCL-HEI: Desirable Regime Domain at Start @ 180

It wasn't long before the system found itself in an undesirable regime basin where illegal trash dumping became the norm as *cooperatives* and even *environmental stewards* could no longer afford the combined expenses of transportation fuel and tipping fees (Fig. 5.8) and joined the action of *uncooperatives* of dumping trash illegally. This became a

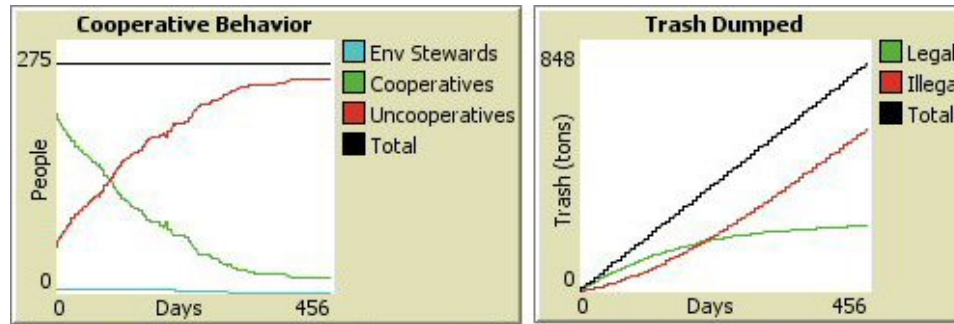


Fig. 5.8 TCL-HEI: Undesirable Regime Domain @ 450

reality, where poverty and low income levels combined with driving distances to dump trash and paying tipping fees having to be paid, created an unfavorable climate pushing residents to dump their trash illegally, regardless of their perceived value orientation towards the environment.

Then, through a collaborative effort first to bring about awareness followed by collective action, resources and capital began to be mobilized in a new way through grass-roots initiatives to form an entrepreneurial business cooperative to manage a local recycling and waste-to-fuels program. Through this increased connectedness and reallocation of not just economic capital but also social and human capital, the social-ecological system again began to shift towards a new position overcoming the negative forces restraining it such as poverty, a poor economy, and high fuel costs (Fig. 5.9). A visible shift could be seen in the decline of uncooperative behavior and an increase in more cooperative behavior along with a corresponding shift in illegal trash dumping and legal trash dumping. As the new program took hold and news grew of its success the

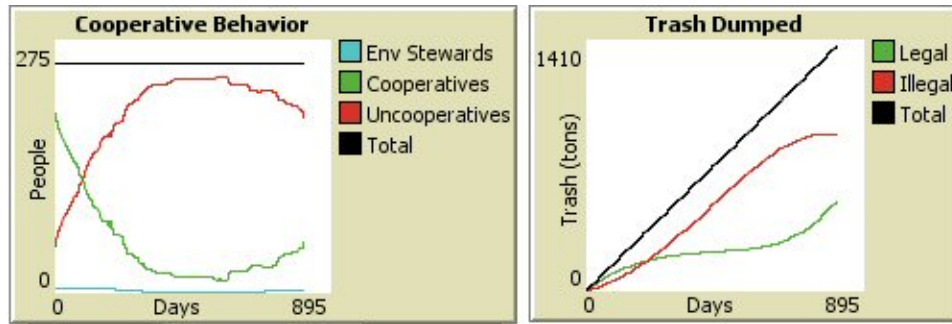


Fig. 5.9 TCL-HEI: Undesirable to Desirable Regime Domain @ 810

landscape configuration of state variables changed sufficiently to cause a regime basin shift leaving the system in a new regime altogether with new dynamics at work influenced by collaborative adaptive capacity building that brought about new behaviors and individual and collective action (Fig. 5.10).

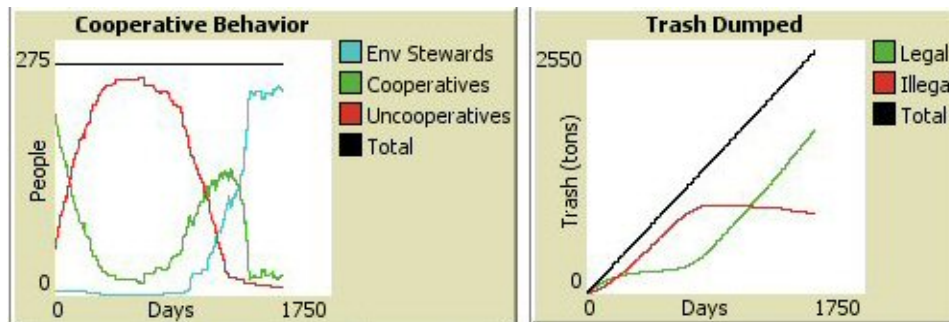


Fig. 5.10 TCL-HEI: Desirable Regime Domain @ 1440

This type of adaptive cycle, as discussed above (Fig. 5.6) can be repetitive and recurring as a system finds itself in a loop. This could certainly happen in the case presented here if, for example, the capital resources were to again be restricted to where the business cooperative managers or politicians weighed in to usurp the funds for pet projects or some alternative development use or perhaps even through theft in the case of corruption and greed. The point being that the coupon dollars would then dry up over

time and people's actions could revert to less desirable ways. Caveats to this happening might be if the system dynamics sufficiently changed over the long-term to where there was no more poverty. In such a case it might even be the cooperative members themselves voting for a diversion of funds away from coupon dollars and into some other community backed social and economic development plan such as a community youth center as one of the Navajo participants so eloquently depicted in an artvoice piece during Phase-I (Fig. 3.18).

RESEARCH AND MODEL RAMIFICATIONS AND USEFULNESS

It is often asked of me, what is your research good for? Is this perhaps too abstract for the Navajo to grasp or utilize? I do not believe this is an abstract idea. The model can certainly present abstract scenarios of *what if* during role-playing or sensitivity analysis exercises. Similarly, the conceptual models could be viewed as being abstract. However, it seemed to me at just about every step of the research process—from conceptualization of key ideas and discoveries to what it has become is grounded in the realization that the Navajo participants were there all the way making it happen. Their photos, artwork and narratives gave rise to the issue of illegal trash dumping. It was their use of the PSFA-CACB model through iterative reflexive consultations that honed and molded the issue of illegal trash dumping into useable ideas that could be put into a model—whether through their focus group, issues mapping or game playing. It was there feedback on the model that in part helped to give direction and focus whether from the name *Taking Care of the Land* or positive feedback on the visual display to the use of turquoise for the

environmental stewards. What remains to be seen is if opportunities will arise for some of them to use and play with the model and inspire others to discover with it.

Usefulness and being pragmatic is fundamental to my research, as this theme has been discussed at various points throughout this dissertation. Addressing the degree of usefulness of my work is partially a matter of how it is applied and at what scale, i.e., at the local level by participants, by local officials, by regional authorities or policy makers at the Navajo Nation level.

At the local level, I believe my research has shown how a participatory exploration using photovoice and artvoice can build collaboration and bring a community together to address local issues and concerns. Photovoice and artvoice are very practical and relatively inexpensive methods that the Houck participants could certainly reengage in to explore other issues or assist neighboring Chapters to adopt such as Oak Springs that at varying times had individuals from Pine Springs visiting the NABI Thursday dinners inquiring about the project and how it could be applied in their community. Furthermore, the participants were beginning to learn the value of the PSFA-CACB model and how it can help drive results while fostering a collaborative spirit of learning and capacity building through its iterative and reflexive process. Application of the PSFA-CACB model does not need to be restricted to community problem solving. The core principles are applicable in a variety of settings and circumstances including regular ongoing meetings whether for business, government or civic organizations; for youth and children's classes where the participants can learn the value of collaborative interaction and engage in a learning style that fosters accompaniment and acquiring a humble posture of learning along with sharing; and at higher educational levels such as schools

and colleges where group structured research projects could benefit from a collective, collaborative and engaged process of learning and exploration. These are but a few examples that cut across scales from the local to National levels. Policy makers at the Navajo Nation level who might be seeking feedback on a particular issue or concern could deploy a structured multi-phased program similar to how my work was structured and unfolded. Setting up such a collaborative program might be a way to explore issues non-prejudicially as teams, comprised of diverse stakeholders, worked together following the guiding structure of the PSFA-CACB model. Working in an environment where there is a healthy sense of unity and willingness to collaborate for the betterment of our fellow human beings can often inspire unexpected results and solutions. Applications of the PSFA-CACB model can help to inspire and guide this process.

There are many practical applications of the model or variations of this model if it were to be customized with the parameters and landscape configuration details of a different scenario or Chapter. Local officials could certainly use it in a capacity similar to the pro-forma case study presented above. Officials at all levels, Chapter, Regional and the Navajo Nation could use the model as a beginning platform to engage in a public discourse on the pros and cons of commencing a pilot program to study the ramifications and feasibility of building a regional or national cooperative clean-energy economy. Such a National discourse could engage both the public and private sectors as well as the academic institutions at all levels. Children and families could be encouraged to get involved with ideas and feedback. They could use the model or similar but simpler agent-based models for educational, learning and discovery purposes. College and university students could get engaged on a more serious note through dedicated research projects

looking at key components pertinent to their individual Chapters or vital cross-scale linkage issues that such a Navajo Nation program would certainly need to address. It could be an initiative throughout the Navajo Nation that could galvanize a people. The focus would be real and practical as the community set goals to mitigate environmental degradation through trash recycling, waste-to-fuels processing and landfill use depletion as well as improve the economy with real job creation and wealth building—all of which would serve the noble goal of raising human dignity.

CONCLUSION

Social action through illegal trash dumping has been impacting the local environment of the Houck Chapter on the Navajo Nation for decades that in turn continues to negatively impact the local community. It is the adaptive capacity of individual participants, which has enabled a local community to arise and make change. In turn, it is through these changes that the adaptive capacity of the community is improving that is having a positive impact on the social-ecological system—perhaps shifting the system’s regime basin into a new basin of attraction that is more desirable. Through this research, I have shown that a synthesis of the PSFA-CACB and TCL-HEI models with a real world social-ecological system issue is not only a novel idea but can be an effective means for building capacity, fostering adaptation, and nurturing positive resilience within a community. This in turn has empowered it to identify and solve local problems, which in this case lead to a mitigation of environmental degradation caused by illegal trash dumping. Further, the tri-phase dual-model exploration illustrated how a community could apply sustainable entrepreneurship to such a problem as illegal trash

dumping and not only mitigate environmental degradation but build individual and community capacity by developing jobs, wealth, prosperity, and human dignity.

Being firmly in the *Anthropocene Era*—a period in humanity’s evolution where human behavior and dominance is significantly impacting the earth’s systems, my research objective was in response to the concern and call of the National Science Foundation (NSF, 2009) and of the International Human Dimensions Programme on Global Environmental Change (IHDP, 2010). This is a call for humanity to develop new strategies to tackle complex anthropogenic issues impacting the global environment and that there should be a focus on human behavior. Humans are intricately tied to the environment and this relationship is reflexive as Effendi (1933) poignantly states:

We cannot segregate the human heart from the environment outside us and say that once one of these is reformed everything will be improved. Man is organic with the world. His inner life moulds the environment and is itself also deeply affected by it. The one acts upon the other and every abiding change in the life of man is the result of these mutual reactions.

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GLOSSARY (Words & Concepts)

The definitions and conceptual explanations below are contextually relevant to this dissertation and come from a variety of mixed sources.

Abductive – alternative conceptual middle ground in research to deductive and inductive methods. Abductive, often used synonymously with retroductive, is a method used in agent-based modeling where phenomena are explained by inferring the generative mechanisms underlying the processes associated with the object of study. Through iterative simulation, the similarities and differences between generated and observed results are compared and then rules are modified to reduce the differences.

Adaptability – The capacity of actors in a system to influence resilience. In a social-ecological system, this amounts to the capacity of humans to manage resilience.

Adaptive capacity - The capacity to adapt and shape change.

Adaptive cycle – A metaphor used in resilience research to describe four commonly occurring phases of change in complex systems. The four phases are: exploitation, conservation, creative destruction, and renewal (also referred to as r, K, omega, alpha).

Adaptive management - a systematic process for continually adjusting policies and practices by learning from the outcome of previously used policies and practices. Each

management action is viewed as a scientific experiment designed to test hypotheses and probe the system as a way of learning about the system.

Anthropocene era – A term coined by ecologist Eugene Stoermer and popularized by the Nobel Prize-winning atmospheric chemist Paul Crutzen to describe a period in humanity's evolution where human behavior and dominance is significantly impacting the earth's systems.

Artvoice – Adapted from photovoice, artvoice is a method used in this dissertation for people to further explore and capture meaningful community issues and concerns that were then expressed through art and a corresponding narrative. In the context of my research it was used in a collaborative format and helped individuals not only identify and express issues that they care about but empowered them to speak out and discuss in front of others about their concerns or issues that were important to them.

Axiology – the study of values particularly relating to values of ethics (right and good) and aesthetics (beauty and harmony).

Baha'i – a world religion dating back to 1844 Persia, founded by Baha'u'llah. Today over 2,100 different tribal and ethnic groups in over 100,000 localities around the world represent it.

CACB – *Collaborative Adaptive Capacity Building*, a formal conceptual model presented in this dissertation as the inner core to a larger conceptual model *Participatory Social Framework of Action* (PSFA).

Capacity building – a concept that emerged in the 1990s among the international development community. It often refers to strengthening the skills, competencies and abilities of people and communities in developing societies so they can overcome the causes of their exclusion and suffering.

Cartesian-Newtonian – is a classical science worldview named after René Descartes and Isaac Newton based on a mechanistic view of human beings and the universe and is often criticized for alienating human beings from their spiritual, moral, and emotional faculties. Proponents of a Cartesian-Newtonian worldview usually have a more materialistic outlook that emphasizes the truth of science, reason, logic, the natural, the material, and the secular while ignoring or even denigrating the truth of religion, faith, intuition, the supernatural, the spiritual, and the sacred.

Coherence-truth - establishes a positive relationship between two things that are the same, two ideas. Rationalism that emerged from the Age of Enlightenment is based on the truth-method of coherence where an idea is one that coheres logically with a set of beliefs already established by a group of people or a society.

Collaborative social research - involves collective research action taken in a social setting where accompaniment between the researcher and those being researched remains reflexive. Typically, both parties are involved in the design and implementation processes and data is shared with the *activists* as feedback to help construct and implement the next phase of the research.

Collaboration – is a recursive process where two or more people or organizations work together through a deep, collective, determination to reach an identical objective by sharing knowledge, learning and building consensus.

Commensurability – two concepts or things are commensurable if they are measurable or comparable by a common standard such as the commensurability of scientific theories or ontological concerns about the *commensurability* between paradigms.

Complex adaptive systems (CAS) – in the context of social-ecological systems CAS involve a great number of simultaneous interacting sub-systems and parts that evolve, manifest aggregate behavior, have the ability to anticipate and adapt, and possess no single governing rule. CAS theory looks at variation and change to system-level responses.

Confirmability – a qualitative measure used to offset quantitative measures such as *validity*. Confirmability can be established through triangulation and a reflexive journal in the absence of a confirmability audit. Collaborative social research, through its integrated

and reflexive approach between the researcher and the participants can offer a form of confirmability as facts are checked and rechecked with peers and participants.

Correspondence-truth – relates to a true idea that positively corresponds to facts as arranged in the observable world. It is the correspondence between an idea and a fact.

Critical realism – pertains to the philosophy of perception where some of our sense-data can and do accurately represent external objects, properties, and events, while other of our sense-data (such as illusions) do not accurately represent any external objects, properties, and events. It highlights a mind dependent aspect of the world, that reaches to understand (and comes to understanding of) the mind independent world.

Deduction – is an inference where the conclusion is of no greater generality than the premises. Deduction seeks to identify the consequence of assumptions. Deductive logic, is reasoning that constructs or evaluates deductive arguments. Deductive reasoning contrasts with inductive reasoning in which a specific conclusion is arrived at from a general principle. Deductive arguments are attempts to show that a conclusion necessarily follows from a set of premises or hypotheses. A deductive argument is valid if the conclusion does follow necessarily from the premises, i.e., the conclusion must be true provided that the premises are true. A deductive argument is sound if it is valid and its premises are true. Deductive arguments are valid or invalid, sound or unsound. Deductive reasoning is a method of gaining knowledge.

Dendrochronology – also known as tree-ring dating is the scientific method of dating based on the analysis of patterns of tree-rings. Dendrochronology can date the time at that tree rings were formed, from many types of wood, to the exact calendar year. Douglas (1935) used this technique to date the presence of ancestral Navajo to the Colorado Plateau from ancient dwelling timber used for building hogans.

Empiricism - Empiricism as brought forth during the Age of Enlightenment (Reason) gave rise in part to our contemporary classical model of science and positivism throughout the period of modernity and may be differentiated from two other means of verifying truth, rationalism and pragmatism.

Endogenous – is used to describe actions or substances from within. In a resilience framework, an endogenous (internal) shock to a system is one that comes from within the system itself such as internal corruption bringing a local government to a standstill.

Entrepreneur – is an owner or manager of a business enterprise who makes money through risk and initiative or a person who is willing to help launch a new venture or enterprise and accept full responsibility for the outcome.

Epistemology – is often referred to as the *theory of knowledge* or literally from the Greek, the study of knowledge or science. It pertains to the branch of philosophy concerned with the nature and scope (limitations) of knowledge seeking answers such as what is knowledge? How is knowledge acquired? How can a given subject be known?

Exogenous - is used to describe actions or substances from without. In a resilience framework, an exogenous (external) shock to a system is one that comes from outside the system itself such as a swift rise in the price of oil due to a war in the Middle East bringing local transportation on the Navajo Nation to a standstill.

Fallibilism – refers to the philosophical principle that human beings could be wrong about their beliefs, expectations, or their understanding of the world. In the most commonly used sense of the term, this consists in being open to new evidence that would disprove some previously held position or belief.

Feedback loops – In systems analysis where there are inputs and outputs, positive feedback is feeding back part of the output to increase the input or what is sometimes called regeneration. Feeding back part of the output that opposes the input is negative feedback or degeneration. In ecological systems, negative feedback is usually synonymous with maintaining stability in a system where as positive feedback amplifies possibilities of divergence giving the system new opportunities to access new points of equilibrium. This is what takes place when a system experiences a regime basin shift.

Generalizability – in reference to research, is the breadth of inferences that can be drawn and focuses on a study's link to theory development and testing. One of the reasons for using the ODD format in agent-based modeling is to try to bring a more common format to agent-based model descriptions and layout in attempts to make them more replicable

and generalizeable. Agent-based models that emphasize stylized facts and laboratory experiments are typically more generalizeable than models based on case studies or contextually based role-playing.

Hermeneutics – as it applies to social philosophy and religion is the study of the theory and practice of interpretation used to unravel communication (written, verbal and nonverbal) and human understanding. In the application of my work it opens a door to fact finding and knowledge building that can be more holistic in approach, allowing for a collaboration of quantitative and qualitative approaches. It is a more holistic approach that allows for the inclusion of important human dynamics such as traditional knowledge and belief systems that fall outside of a traditional western-scientific approach (see Cartesian-Newtonian).

Hogan – is a Navajo dwelling that is typically round or cone shaped and made of wood and mud with the door facing east to welcome the rising sun. To many Navajo, the hogan is considered sacred that is why moving in a clockwise direction is practiced to resemble the direction the sun moves. For this reason, it is respectful of a person entering a hogan to move to the left, continuing around in a clockwise direction.

Holism – in the context of systems thinking, a system and its parts and properties is viewed as a whole and not as a collection of parts giving rise to the notion that the whole is greater than the sum of the parts. Holism is often viewed in contrast to reductionism

that tries to understand and explain complex systems solely through the reduction of its fundamental parts.

Induction – also termed inductive reasoning is reasoning that evaluates propositions that are abstractions of observations of individual instances of members of the same class to arrive at a general conclusion by specific examples. It is a research method that seeks to identify pattern and that is more closely associated with agent-based modeling than deductive methods. Through inductive logic the researcher starts with contradictory findings and searches for a pattern in the data that might explain the specific observations.

Interpretivism – also termed interactionism is a line of inquiry set upon the premise that natural and physical science methods are inappropriate at analyzing social phenomena (human discourse and action) and that meaning is produced and understood through the interactions and observations of interactions of individuals.

Modernism - encompasses the activities and output of those who felt the "traditional" forms of art, architecture, literature, religious faith, social organization and daily life were becoming outdated in the new economic, social, and political conditions of an emerging fully industrialized world. Modernism explicitly rejects the ideology of realism. Modernism also rejects the lingering certainty of Enlightenment thinking, as well as the idea of a compassionate, all-powerful Creator.

NABI – Native American Baha’i Institute established in the 1970s on the Navajo Nation in the Houck Chapter (see Chapter 2).

Naïve realism – states that the mind perceives, through our senses, a direct awareness of the external world. The realist view is that objects are composed of matter, occupy space and have properties, such as size, shape, texture, smell, taste and color that are usually perceived correctly. We perceive them as they really are. Objects obey the laws of physics and retain all their properties whether or not there is anyone to observe them.

Nonlinearity – in systems thinking this generally refers to a situation that has a disproportionate cause and effect—for example the well known butterfly metaphor flapping its wings in Asia as being linked to the causation of a storm in some other part of the world. In the resilience framework, a complex system’s configuration and linkages of its state variables would exhibit nonlinearity with disproportionate causes and effects and these variables change at varying scales of time and space.

Normative adversarialism – a society that accepts contests and conflict as being normal and necessary models of social interaction, depicting a culture of contest.

Objectivism – is the philosophical standpoint that stresses objectivity and realism with the conviction that reality is mind-independent.

ODD – overview, design and detail. This is an agent-based protocol format used to assist with replicability by presenting the model design in a consistent format.

Ontology – deals with the nature of being, existence or reality as such, as well as the basic categories of being and their relations. Traditionally listed as a part of the major branch of philosophy known as metaphysics ontology deals with questions concerning what entities exist or can be said to exist, and how such entities can be grouped, related within a hierarchy and subdivided according to similarities and differences.

Photovoice - Photovoice is a participatory qualitative research method that can be collaborative as in the case of my work that has a focus towards community problem-solving through critical consciousness and participatory documentary photography that gives voice to local people.

Positivist – or positivism is based on the notion that scientific data (natural and social) are derived from sensory experience and logical and mathematical treatments of this data comprise the sole and exclusive source of all authentic knowledge. Data that is obtained and verified from the senses is empirical evidence.

Postmodernism – is a conceptual framework that is critical of modernism thinking such as the possibility of objective knowledge of the real world and considers the ways in which social dynamics such as power and hierarchy affect human conceptualizations of the world to have key effects on the way knowledge is constructed and used.

Postmodernism advocates idealism, constructivism, relativism, pluralism and skepticism in its epistemology.

Postpositivist – also called post empiricists, believe that human knowledge is not based on rock-solid foundations, but rather upon human conjectures that can be modified or withdrawn in the light of further investigation. Yet, post positivism is not relativism as it retains the notion of objective truth.

Pragmatic-truth - Pragmatism results in pragmatic-truth that is derived from the usefulness of an idea that violates neither coherence-truth nor correspondence-truth.

PSFA – *Participatory Social Framework of Action* is a formal conceptual model introduced in this dissertation that encompasses a core inner model *Collaborative Adaptive Capacity Building (CACB)*.

Rationalism - Rationalism that emerged from the Age of Enlightenment is based on the truth-method of coherence where an idea is one that coheres logically with a set of beliefs already established by a group of people or a society. In its modern sense, the criterion of the truth is not sensory but intellectual and deductive in a method.

Regime shift – in a resilience framework is a shift in an ecosystem or a social-ecological system whereby a threshold is passed and the core functions, structure, and processes of the new regime are fundamentally different from the previous regime.

Relativism – a conceptual theory stating that there is no absolute truth or validity. This might be due to differences in perception between individuals that gives rise to only relative and subjective value, as truth is always relative to some frame of reference such as language and culture. It is often interpreted as saying that all points of view are equally valid.

Resilience – is the capacity of a system to absorb disturbance and reorganize while undergoing change to retain essentially the same function, structure, identity, and feedbacks.