<u>Hierarchy of Ecosystem Function:</u>

By: John D. Liu
Director, Environmental Education Media Project (EEMP)
Rothamsted International Fellow for the Communication of Science (Rothamsted Research)
October, 11, 2008 - Nairobi, Kenya

As I write this essay the world faces several massive crises. The world's financial system is being described as enduring a "Tsunami" and "the most serious financial crisis since the great depression". Many people are afraid that their savings, jobs, even their homes are threatened in this "financial meltdown". Simultaneously with this financial crisis we are becoming more and more aware of long-term environmental problems that are manifesting serious and potentially catastrophic outcomes. Alarming data is coming from many sources, artic ice is melting, coral reefs are dying, fisheries are seeing the apparent disappearance of entire species, ancient forests are being cut down, biodiversity is being reduced, deserts are growing, fresh water is under stress, agricultural productivity is challenged by the loss of natural fertility, and the competition for land from bio-fuels and urbanization.

Several questions emerge. How can we make sense of all the available information? What is important and must be addressed with vigor and concern and what is a secondary issue that is simply a symptom of the fundamental problem? Is there some way that we can take this moment as an opportunity to address the deep fundamental problems that we face? Is there some way to ensure that we come out of this crisis with sustainable systems rather than simply addressing the superficial manifestations of the underlying systemic dysfunction?

For some time now I have been entertaining the thought that all *(or at least very many)* of our problems are actually interconnected and are in fact part of a chain reaction of disruptions that are logically sequential. This suggests that in order to address them we will have to understand and identify the initial disruption and all the following disruptions and address each disruption all the way back to the initial one in order to fundamentally correct the problems. This is a challenging thesis because we have so many opinions, assumptions, preconceived ideas and habitual behaviors. Many people I have met do not believe that our problems can be solved. Others are ignorant of many aspects of individual systems not to mention the complexity implied by the interaction between synergistic and symbiotic ones. Obviously they and millions of others will be hard pressed to effectively address problems that they do not understand. I feel that it is important to try to express my thoughts in the hopes that they can inform others and together we can find ways to emerge from our current crises in a more sustainable condition.

Through the documentation and contemplation of large-scale damaged ecosystems I have observed certain hierarchical characteristics of ecosystem function and dysfunction. These observations suggest that human impact on ecosystem function is in very large part explainable. Understanding and explaining these impacts also points toward rehabilitation strategies that could return ecosystem functions that have been lost over long historic time horizons and over very large areas. Although few authors have stated this specifically, there is a large amount of data that corroborates various aspects of this work. This paper begins to summarize these observations and evaluate the relevance of these findings for policy and action on a range of ecological challenges including climate change, food insecurity, hydrological dysfunction, desertification, poverty, disparity, sustainable development, etc.

My observations suggest that human beings have inadvertently created a chain reaction of systemic failures, with certain identifiable failures occurring first, and these then caused failures of other systems that cascaded toward complete collapse of functionality. This scenario suggests that negative effects of dysfunction are accumulative, points to the potential of feedback loops and non-linear outcomes that may seem unconnected but can be traced back to specific human impacts in other areas. This suggests that analysis of natural systems may also shed light on why the financial systems are impacted. When using this paradigm to view historic and contemporary land use I have noted that the theoretic outcomes seem to closely parallel the actual outcomes. This may have value in many ways, including as a tool kit for analysis that would dispel doubt and help communicate scientific principles to inform policy and development decisions. This also supports a growing body of evidence that suggests that it is possible to rehabilitate large-scale damaged ecosystems including returning ecosystem function that has been lost over long periods of time and broad areas.

Below is a linear summary of my thoughts on the hierarchy of ecosystem dysfunction followed by short descriptions of each stage. This description may help policy makers and others seeking to understand the processes that are determining critical outcomes (e.g. hydrological function, biodiversity, fertility, productivity) of their decisions and actions.

Summary of the Hierarchy of Ecosystem Dysfunction:

Biodiversity Loss:

↓

Reduction of Biomass - Loss of Photosynthesis

↓

Reduction in Carbon Sequestration

↓

Reduction of Accumulated Necromass (Soil Organic Matter)

↓

Loss of Soil Stability

↓

Loss of Nutrient Cycling (Nitrogen, Phosphorous, Potassium, secondary nutrients, micro-nutrients)

↓

Loss of Hydrological Regulation (Natural Infiltration and Retention of Rainfall)

↓

Systemic dysfunction at this scale suggests very large disruption.

↓

Leading to Continuous, Accumulative, Predictable Outcomes (soil erosion, loss of fertility, floods, drought, mudslides, dust storms, food insecurity, poverty, disparity and Climate Change, Unchecked Population Growth)

Biodiversity Loss:

In broad strokes what I have observed is that human impact on natural ecosystems can be seen to have begun with the reduction of biological diversity. Originally, the impact came from the hunting of large mammals to extinction. Gradually this began to spread to other families of species (i.e. birds, fish, amphibians). With the advent of settled agriculture, human induced land use changes began a long-term process of selection of plant species, originally for food crops but eventually for many purposes (fuel, fiber, building materials, etc.). The reduction of biodiversity is of concern both because of the possible loss of unclassified and irreplaceable genetic materials, which may have vital roles in symbiotic life cycles and because it has triggered a series of system failures that lead to identifiable and predictable outcomes.

Reduction of Biomass:

Initially the reduction of biodiversity (as in hunting large species to extinction) did not necessarily cause the loss of biomass. It is hard to know but it seems logical that the biomass might have been replaced by other species. However, significant reductions of biomass are logical outcomes as reduction of biodiversity gained momentum over historic time. This can be seen in deforestation, in lower biomass in monocultures such as agricultural crops, in quantitative losses from replacing natural forests with tree plantations and this would increase as systemic disruption became widespread. The loss of biomass means a reduction of photosynthesis. The reduction of biomass is also consistent with the outcomes we see in large degraded ecosystems wherever human centers of power and affluence have failed due to ecosystem collapse.

Reduction of Accumulated Necromass (Soil Organic Matter):

Reducing the annual production of biomass, necessarily reduces the accumulated necromass. I define necromass as all biomass that is no longer living, having laid down its body to nurture the next generations. *(This could also be thought of as soil organic matter but I believe that the idea of necromass can be seen as directly relating to the generation of biomass and thus may be a better term.)*
Necromass to my mind is a better representation that “Plant Litter” or “Soil Organic Matter” because it encompasses both these states and corresponds more exactly to biomass.

Loss of Soil Stability:

The reduction of biomass and necromass leads to distinct changes in soil structure. The loss of living root systems and the loss of rotting dead root material alters friability (and compaction) and lowers the organic matter. Loss of organic matter increases the percentages of geological soils. These changes lead related effects where nutrient cycling, water infiltration, water retention, soil moisture, soil temperature, microbial biomass, are all dramatically degraded.

Loss of Nutrient Cycling (Nitrogen, Phosphorous, Potassium, secondary nutrients, micro-nutrients):

The loss of biodiversity, biomass, necromass, soil organic matter also necessarily lowers the cycling of nutrients. This effects a wide range of nutrients from primary nutrients, including nitrogen, phosphorous and potassium but also secondary and micronutrients. This has major impacts on the possibility to grow agricultural crops without chemical fertilizers and effects nutritional values of the crops that are grown. The nature of this nutrient loss is accumulative and is a major factor in an unsustainable development trajectory.

Loss of Carbon Sequestration:

Given the extreme emphasis on carbon disequilibrium and especially on emissions of carbon dioxide into the atmosphere it is important to note that carbon disequilibrium is connected to the chain reaction of dysfunction that has occurred. The reduction of biodiversity, biomass, necromass, means that photosynthesis has been disrupted over very broad areas of the earth. There are two important aspects to this. First the carbon we are emitting into the atmosphere was originally fixed as ancient photosynthesis (the origins of coal, oil and natural gas). Second is the fact that the biomass and necromass would sequester carbon in the plant material and in the soils except for the fact that we have vastly reduced vegetation cover and soil organic matter.

Loss of Hydrological Regulation (Natural Infiltration and Retention of Rainfall):

The systemic loss of biodiversity, biomass, necromass, soil stability, naturally leads to the loss of natural infiltration and retention of rainfall. This phenomenon is of huge importance and suggests many important things. First among them may be that several critical measurements we are making now may reflect dysfunction rather than functionality and so could be significantly altered. In my experience I have noted that this is extremely applicable in many parts of Africa. In Rwanda, Tanzania, Kenya, Ethiopia I have seen this process at work. Once viable areas have been turned into "Arid" and "Semi-Arid" areas by the disruption of vegetation cover and reduction of biological soil function. This phenomenon is not limited to Africa, anywhere on earth that human being removes biodiversity, biomass and disrupts the living soils you will get the same outcome. The fact that this is true suggests that a principle can be extracted from this. This also suggests that because the disruption is physical that only a physical response will possibly restore the equilibrium. The solution to many of our problems may be contained in this understanding.

Systemic Dysfunction at this Scale Cannot Help but Affect Climate Change:

Going from continent to continent looking at the impact of human beings on ecosystem function we must note that human beings have seriously limited biodiversity, biomass, necromass, soil stability and natural hydrological regulation. At this scale it is clear that we are affecting the climate. It is true that excessive consumption has led to excessive emissions of CO_2 into the atmosphere but it is also true that simultaneously with this vast areas of the planet have lost the ability to fix carbon through photosynthesis. It is logical to conclude that the combined effects of these impacts, is carbon disequilibrium of a scale affecting natural climate regulation.

And leads to Continuous, Accumulative, Predictable outcomes:

If we imagine early human history and we note that initially human beings began to limit biodiversity by hunting certain large mammal species to extinction, then human beings began to cultivate the soil for increasingly fewer agricultural crops as well as increasingly free ranging a few domesticated ungulates, we can see that the reduction of biodiversity is a long-term trend. If we play this scenario out over long time horizons, years, decades, centuries and millennia then desertification, fresh water losses, poverty, disparity and climate change are all logical outcomes. The fact we are seeing and experiencing all of these things does not seem confusing from this perspective, it seems entirely predictable.

If we build a financial system that does not reflect an understanding of ecosystem function then that financial system contains serious and fundamental flaws. If we do not value biodiversity, the role of biomass in photosynthesis, the natural infiltration and retention of rainfall, natural nutrient cycling leading to fertility and productivity, then we have not understood what is the basis of life on earth and we have valued other lesser infrastructural aspects that are dependent on the underlying functionality. Explained this way it is not surprising that we are in the throes of a financial crisis.

Logical Conclusions:

With 6.8 billion people and adding a billion more people approximately every 12 years even without the current crises we need to seek sustainable outcomes. If we can understand that human impact is a species impact and that it stretches back over the generations to the beginnings of human history then we can identify where and what disruptions we have caused. This also suggests how we might put our efforts to restore ecosystem function, equilibrium and sustainability.

By examining human impact over historic time we can understand and succinctly describe the main ways in which we have altered the natural environment. Essentially we have limited biodiversity, lowered biomass reducing photosynthesis and reducing the accumulation of necromass (soil organic matter), which has caused the reduction of nutrient cycling including the ability to sequester carbon and this has very significantly disrupted the infiltration and retention of rainfall leading to massive redistribution of energy by passing the kinetic energy in the waters to other places on the earth and also by the loss of potential energy in photosynthesis (most likely the larger loss).

We can closely study ecosystem dysfunction or we can try to understand what is the nature of ecosystem functionality. When we understand functionality we can see that there are clearly certain ecosystem functions, which are vital to life, and other considerations, which are secondary to these primary functions. We have clearly not always put our emphasis in the right place.

When we study ecosystem function we begin to see that there is an implied inverse to disruptions caused by human beings. If we take the hierarchy of ecosystem dysfunction and reverse it we can see a path that is suggested. We need to ensure that all rainfall is infiltrated and retained where it comes down. This can be done by bio-physical means. By doing this we can reverse the wanton loss of nutrients from erosion and can encourage the restoration of biodiversity and biomass. With the return of biodiversity and biomass there will be increased carbon sequestration through increased photosynthesis and an increase in accumulated necromass (soil organic matter), which will help to restore nutrient cycling. If this process is understood and all policies and practices follow these principles then the outcome will be sustainable.

There is evidence on every continent that it is possible to restore ecosystem function if we understand the hierarchy and mechanisms of functionality. But we have yet to take this knowledge on as a species. It is not sufficient for experts to know this. It is necessary that this becomes common knowledge.

Humanity stands at a crossroads in our history. We must make a choice that will decide what the earth and life on earth will be like in the future. We can choose to learn what are the fundamental determinants of ecosystem function and the basis of human life and adapt to this or we can continue to mistakenly think that the societal and economic infrastructure that we have built up over the course of human history is somehow independent of ecosystem functionality.

To maintain business as usual given the multiple crises we face is a very high-risk proposition with a high probability of disaster.

To face the future with enlightenment and determination, reflecting the knowledge we have and gained and the principles that we know to be true, represents an opportunity to address many historic and ecologic problems and come out on the other side with a fair and sustainable future for everyone.

No single individual can decide the future, this will be determined by what humanity as a species understands and how quickly and effectively we act. But we can all decide to do our best to participate and contribute. I hope that this short summary can help to increase understanding and dialogue that will lead to a sustainable outcome.

John D. Liu
Director, Environmental Education Media Project (EEMP)
Rothamsted International Fellow for the Communication of Science
PhD Candidate (Research), Soil Sciences Department
School of Human and Environmental Studies, University of Reading (UK)

Ci Yun Si # 11, Chaoyang District, Beijing, China 100025
Mobile Tel: 86-13911565016, Studio Tel: 86-10-8551-1054
<*johnliu@eemp.org*> <*john.liu@bbsrc.ac.uk*>
www.eempc.org *www.earthshope.org*