Congressional Briefing Paper on Wetlands & Climate Change

Prepared by Dr. Robert Costanza (*Cody Jordan*)

Valuing Wetlands and Implications of Climate Change

About the presenter

Dr. Robert Costanza is a professor in the Institute for Sustainable Solutions at Portland State University, USA. He is also a Distinguished Research Fellow at Ecological Economics Research Center of New Zealand (EERNZ), a Senior Fellow at the National Council on Science and the Environment (NCSE, Washington, DC), and a Senior Fellow at the Stockholm Resilience Center. His previous posts include Director of the Gund Institute of Ecological Economics and faculty positions at the University of Maryland and Louisiana State University.

Dr. Costanza takes an interdisciplinary approach to research, especially in the merging of ecology and economics. He was a co-founder of the International Society for Ecological Economics and was chief editor of the Ecological Economics journal from 1989-2002.

His major awards include a Kellogg National Fellowship, Society for Conservation Biology Distinguished Achievement Award, a Pew Scholarship in Conservation and the Environment, an honorary doctorate from Stockholm University, and other accolades. He has authored or co-authored 400+ journal articles and over 20 books. His work is widely cited (in 6000+ articles) and his seminal paper in Nature, "The value of the world's ecosystem services and natural capital," is one of the most cited papers in the field of ecology. Much of his recent published work has focused on the value of natural wetlands, particularly coastal wetlands, for storm damage abatement, along with sustainable solutions to address hydrology in low-lying, coastal areas like New Orleans (Costanza et al. 2008; Costanza et al. 2006a; 2006b; Martinez et al. 2011). He is well-known for using models to value intact wetlands monetarily for their role in reducing storm damage and for quantifying their ability to reduce loss of human life during storm events.

Dr. Costanza’s research touches on many aspects of ecology, economics, and urban planning. As the world moves into the 21st century and faces new threats from a changing climate, his expertise will be very valuable to land managers, policymakers, and officials involved with development. His testimony at this briefing will provide insight into the value of ecosystem services, the integration of economic and natural capital, new ways of valuing of human quality-of-life, and achieving sustainable growth both economically and environmentally.

"In the past, only human-made stocks were considered as capital because natural capital was superabundant. Human activities were at too small a scale relative to natural processes to interfere with the free provision of natural goods and services. Expansion of human-made capital entailed little or no opportunity cost in terms of the sacrifice of services of natural capital. Human-made capital was the limiting factor in economic development, and natural capital was a free good. But we are now entering an era, thanks to the enormous increase of the human scale, in which natural capital is becoming the limiting factor. Human economic activities can significantly reduce the capacity of natural capital to yield the flow of ecosystem goods and services upon which the very productivity of human-made capital depends."

-Robert Costanza (from Investing in Natural Capital, 1994)

Introduction to wetlands

Formal wetland definitions abound. Some are wide in scope and some quite narrow. Generally speaking, wetland characteristics include: standing water during a significant portion of the growing season or year-round, plants that can survive and thrive in very wet conditions (hydrophytes), and different soil types from adjacent upland sites (Mitsch and Gosselink 2007, pp. 27-28). This sounds relatively straightforward, but there is a substantial amount of gray area when defining a wetland. For example, a wetland may be completely inundated with water for half of the year, but visitors to this hypothetical wetland during the other half of the year may not see any water at all. Wetlands can be tidal or non-tidal and saltwater, brackish, or freshwater. These, among other aspects, can make defining the boundaries of wetlands quite difficult. Nevertheless, one of the most widely-used definitions in the United States is from the U.S. Army Corps of Engineers in 1984:

"The terms 'wetlands' means those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soils. Wetlands generally include swamps, marshes, bogs, and similar areas."

(33 CFR 328.3(b))

Wetlands are often thought of as transitions between terrestrial and aquatic ecosystems; e.g., a swampy area between a forest and a river or a mangrove between a forest and the ocean. The most important theme is that water plays a substantial role in the wetland's biological composition, its hydrology, and its soil chemistry. Broadly speaking, wetlands make up about 5-8% of the earth's land surface (Mitsch and Gosselink 2007). They are among the most productive ecosystems in the world and many types of wetlands exhibit high levels of biodiversity, as well as important habitat for migratory birds and endangered species. Some one-half of endangered species in the United States rely directly or indirectly upon wetlands (US EPA 2012).

Wetlands also provide an array of ecosystem services. Ecosystem services in a nutshell are benefits and resources that humans take, directly or indirectly, from an ecosystem. From a wetland, these services abound— erosion control, waste treatment, water regulation, sediment retention; and more tangible items such as sources of food and medicine. In one example, the Congaree Bottomland Hardwood Swamp in South Carolina improves water quality equivalent to a $5 million water treatment plant (US EPA 1993). The global suite of ecosystem services from all ecosystem services is estimated conservatively to be worth $33 trillion per year, while the global GNP is barely half that number at $18 trillion per year. Interestingly, some 15% of that total of $33 billion comes from wetlands, which slightly out-value forests on average ($4.9 trillion/year versus $4.7 trillion/year) (Costanza et al. 1997).

A brief introduction to climate change and greenhouse gases

The anthropogenic emission of certain gases which contribute to the so-called greenhouse effect became significant at the onset of the Industrial Revolution in the middle of the 18th century. These gases trap heat in the Earth's atmosphere and can lead to an increase in average global temperatures. Concentrations of greenhouse gas emissions and mean global temperature increase are highly correlated and this will have a myriad of impacts on the natural environment. With regard to wetlands, the main impacts will be those that concern water: sea level rise due to melting ice caps and thermal expansion of water and the warming (or drying up altogether) of water which biota depend upon (Mitsch and Gosselink 2000; Steinfeld et al. 2006).

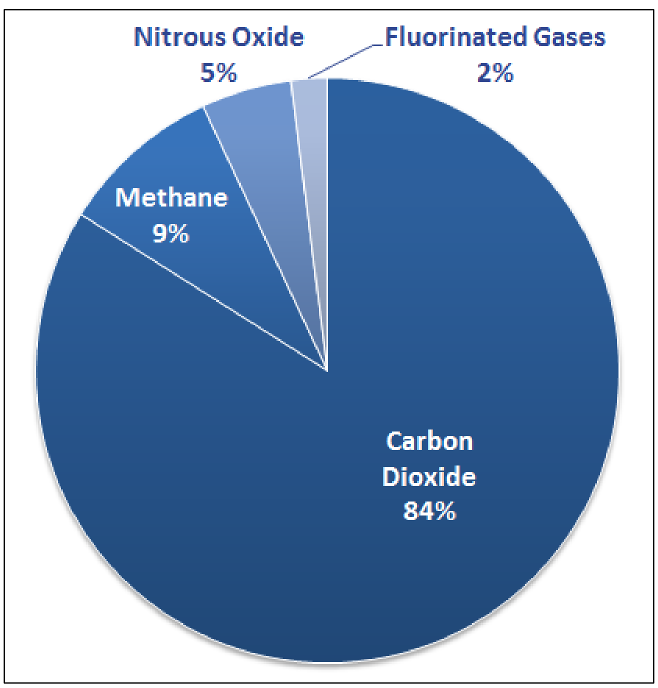

Figure 1. US Greenhouse Gas Emissions, 2011. Data and graph from the US Environmental Protection Agency.

The three most significant greenhouse gases emitted by humans in terms of abundance and/or global warming potential (GWP) include methane (CH_4), carbon dioxide (CO_2), and nitrous oxide (N_2O). The GWP of carbon dioxide is 1, because it is considered the baseline. The GWP potential of methane is approximately 21 and 300 for nitrous oxide, meaning 21 and 300 times more global warming potential than carbon dioxide respectively (Steinfeld et al. 2006). Figure 1 uses 2011 data to show anthropogenic emissions of major greenhouse gases in the United States.

Methane is produced naturally from geologic emissions, vegetation, and other sources, but the largest natural source is from wetlands (US EPA 2010). Methane emissions from wetlands will actually increase as temperatures increase creating a positive feedback loop. Nevertheless, the amount of methane produced by natural sources is significantly outweighed by human-related emissions.

Regarding anthropogenic sources, methane is primarily produced as a byproduct from landfills, wastewater treatment, industry, and agriculture-- especially animal agriculture. When all greenhouse gases were equated to CO_2 equivalents, over 50% of all human-caused greenhouse gas emissions come from livestock production (especially via methane; livestock production is also significant for wetlands in that it generates uses enormous amounts of arable land, fresh water, and nitrogen fertilizer through the production of livestock, and their feed, processing, and transportation [Steinfeld et al. 2006; Koneswaran and Nierenberg 2008; Goodland and Anhang 2009]).

Nitrous oxide is emitted anthropogenically from agriculture via nitrogen-based fertilizers, burning of fossil fuels, and in various industries. Fluorinated gases (e.g., HFCs, PFCs) are released in small quantities through various industries. All fluorinated gases are entirely synthetic, meaning they have no natural sources. Fluorinated gases have very high GWP values— the highest known GWP value is for sulfur hexafluoride (SF_6) at 23,900 (US EPA 2010). These other greenhouse gases with their higher GWP values are still significant despite their relatively small concentrations versus carbon dioxide, and should not be forgotten when researching, discussing, or creating legislation regarding global climate change.

Climate change and wetlands: it’s all about the water

The primary challenges posed by climate change worldwide, whether ecological or humanitarian, will be due to climate change’s impacts on water. As previously noted, sea level rise can affect coastal wetlands— either by destroying them completely or degrading freshwater wetlands with saline water. While estimates of mean global sea level rise vary widely, from 50 to 200+ cm, it has be suggested that half of wetlands recognized as important by the Ramsar Convention would be threatened (Nicholls 2004).

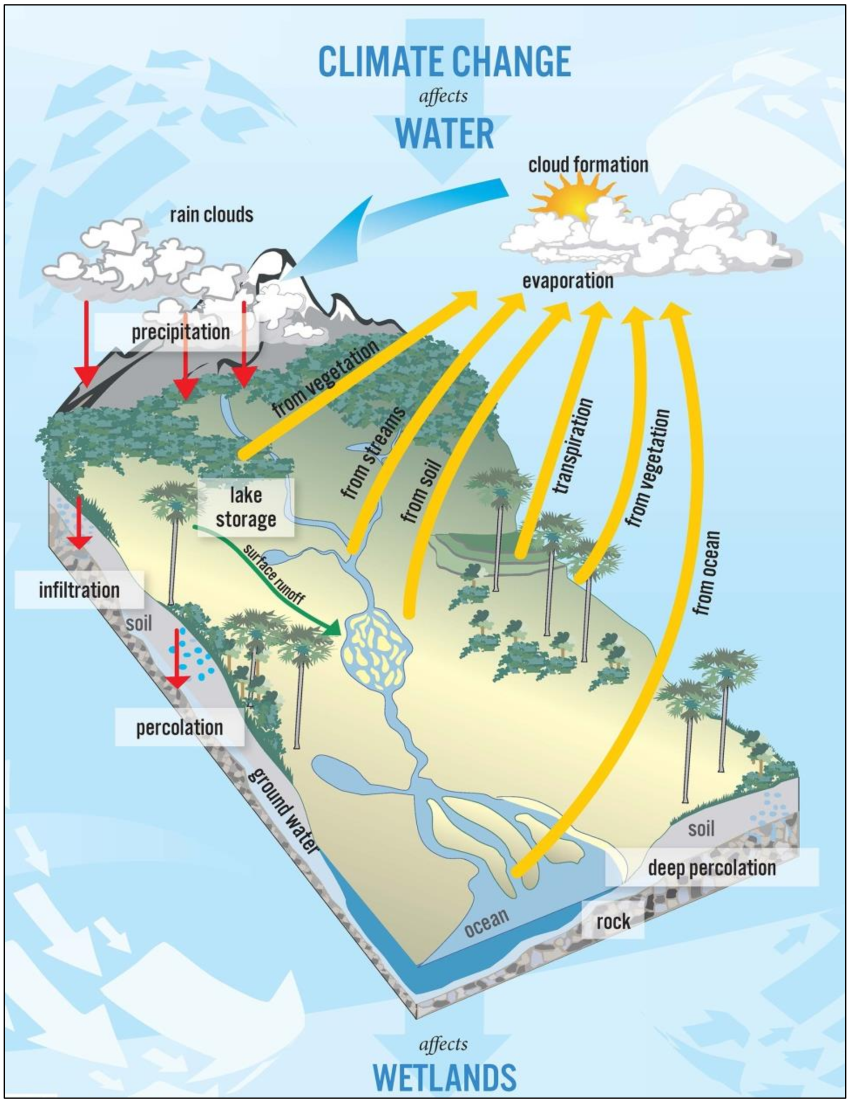

Figure 2. The inflows and outflows of water from wetlands. Edited from Ramsar 2007.

Hydrology, or the movement and distribution of water, is of course central to the integrity of wetlands. Human alteration of hydrology in coastal areas via structures such as levees, dikes, canals, etc. will further exacerbate threats to wetlands from sea level rise. The trapping of wetlands between the rising sea and dry, upland areas (or artificial structures) has been termed "coastal squeeze" (Nicholls 2004).

Changes in precipitation will substantially affect both coastal and inland wetland systems. Precipitation changes will alter surface and groundwater inputs and outputs from wetlands as well as alter the balance of water from precipitation and evaporation. Certain inland wetland areas may dry up permanently or semi-permanently, thus affecting numerous migratory bird species and other organisms which depend on these wetlands. Figure 2 details some of important pathways of water within and around a wetland and how these pathways will be affected by climate change.

So wetlands will change— what's the big deal?

This brings us back to our consideration of ecosystem services from wetlands. In addition to the effects on a number of biota which depend on wetlands, including numerous endangered species, humans also depend on wetlands. Wetland ecosystem services discussed previously can be quite valuable, if often overlooked, such as water purification, sediment retention, and protection against flooding.

It is these services which directly and most prominently affect human livelihood and well-being that compromise the bulk of my recent research. Research has shown that not only do humans depend on wetlands for food, fiber, and these other services, but wetlands provide enormous amounts of protection in the event of flooding and coastal storms. These protections can be measured in both financial ways (i.e., dollars saved by wetlands) and in human life (i.e., lives potentially saved as wetlands buffer against floods and storm surge). For example, research has shown that the presence of coastal mangrove wetlands in Southeast Asia was significantly correlated with wave attenuation (Bao 2011) and countries with the most degraded mangroves suffered the most damage (both in terms of human life and property damage) from the 2004 tsunami (Kathiresan and Rajendran 2005; Costanza et al. 2008). Coastal wetlands throughout the United States were estimated to provide over $23 billion annually in storm protection services (Costanza et al. 2008).

The notion of placing financial values on ecosystem services has been somewhat controversial. For decades, ecologists and biologists tried to convince the public and legislators that nature was intrinsically worth saving and that no dollar value could be place on nature. Many aspects of nature are considered irreplaceable and thus cannot be "bought" back if damaged or lost entirely. Nevertheless, this is somewhat of a false dichotomy. My research has shown that ecosystem services, including those from wetlands, can and do translate to real dollars saved (e.g., the Congaree Bottomland Hardwood Swamp as discussed earlier). Hereafter, we will examine some of these ideas using New Orleans as a case study.

Examining New Orleans

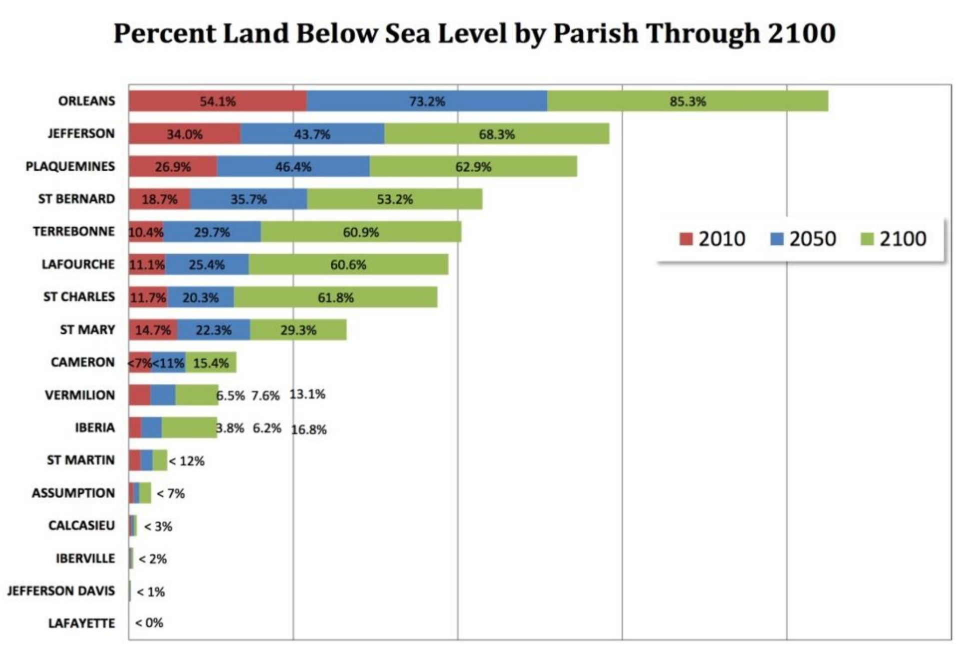

Figure 3. Over half of the land area of Orleans parish is below sea level currently; this is expected to increase dramatically by 2100. Data from: http://lagic.lsu.edu/rsgis/2012/Presentations/osborn.pdf

We will look at New Orleans because the greater Louisiana area has large reserves of wetlands which are experiencing the largest declines of any coastal wetlands in the US, but also because large hurricanes (like Katrina and Rita which significantly affected New Orleans and other areas of the Gulf coast) are expected to increase in both frequency and severity (Knutson 2008). Wetland loss from 1985-2010 in Louisiana was 16.5 square miles annually— this equates to the area of one football field per hour in wetland loss (Couvillion et al. 2011). Additionally, all of the wetlands forecasted prior to Katrina to be lost through 2050 were actually lost during Katrina alone.

New Orleans also presents special challenges for post-Katrina re-development. An enormous percentage of the land area within the Orleans parish is below sea level, and this is expected to continue (Figure 3). Should New Orleans re-build the status quo and hope it does not all get washed away or inundated with water again, or should new strategies be implemented? I propose, and suggest that research supports, the implementation of new strategies. Namely, new development should not occur in excessively low-lying areas that are known to flood easily unless architectural changes are made and new city-planning techniques are integrated into the area.

Damaged levees and canals should not be rebuilt; rather, we should attempt to restore natural hydrological conditions. Canals and levees can actually interfere with natural methods of flood control. Levees have been built to protect homes in the flood plain of the Mississippi River, for example. Ideally, no new homes would be built in these flood plains or other flood-prone areas (Costanza et al. 2006a). The flood plain and other wetlands should be seen as protective barriers between development and storm waters, as discussed with mangroves in Southeast Asia. New development should be pursued with hydrology in mind from the very beginning, not as an afterthought or ignored completely.

Wetland restoration and conservation are important not just for mitigating climate change through carbon sequestration (and minimizing disturbance of methane within wetlands), but also because they help to ameliorate the effects of increased storm severity and frequency that will occur under climate change. Restoring and conserving wetlands along with what could be perceived as a dramatic re-thinking in development sounds expensive.

However, consider that more intact coastal wetlands would have protected both human life and property during storms like Katrina. The status quo is also expensive: re-building all the damaged or destroyed canals and levees will cost billions. However, all of the ecosystem services produced by Louisiana coastal wetlands, including storm protection, are estimated to be worth $12,700 per hectare per year. When we consider only the wetlands lost *prior* to Katrina (some 480,000 hectares), that works out to ecosystem services worth some $6 billion per year (Costanza et al. 2006b; Barbier et al. 2013). Simply put, restoring Louisiana's wetlands would not be cheap, but it would pay for itself both monetarily and increased quality of life.

Concluding remarks

In summary, all parties— city planners, local officials, scientists, engineers, and developers— should work together to implement *smart* development. The value of so-called 'natural capital' should be considered: how will development affect the natural capital? How will the effects on that natural capital affect the citizenry? And we should remember that ecosystem services and human welfare are inextricably linked.

Wetlands are important for a variety of reasons, not the least of which is their direct and indirect benefits to humans. Wetlands are being lost at incredible rates due to a number of factors, but are especially vulnerable to climate change. The upshot is that their restoration can also be an important tool for mitigating climate change while also providing numerous ecosystem services to us. We should strive to encourage smart development, consideration of natural capital, and remember the fundamental relationship between the two.

"Wetlands/biodiversity and climate change are interlinked. Climate change threatens these important ecosystems and the services they provide for human welfare.

> *"[Wetland] ecosystems are already declining faster than any other biome, and climate change will exacerbate this problem largely because its main impacts will be on water…*
>
> *…Wetlands and climate change are interlinked. Climate change threatens these important ecosystems and the services they provide for human welfare."*

Ramsar COP10 DOC.25

> *"What this study makes abundantly clear is that ecosystem services provide an important portion of the total contribution to human welfare on this planet. We must begin to give the natural capital stock that produces these services adequate weight in the decision-making process, otherwise current and continued future human welfare may drastically suffer...*
>
> *…Because ecosystem services are largely outside the market and uncertain, they are too often ignored or undervalued, leading to the error of constructing projects whose social costs far outweigh their benefits."*

Costanza et al. 1997, Nature

References

Bacon, P. 1997. Chapter 1: Wetlands and biodiversity in: Halls, A.J. (ed.), 1997. Wetlands, Biodiversity and the Ramsar Convention: The Role of the Convention on Wetlands in the Conservation and Wise Use of Biodiversity. Ramsar Convention Bureau, Gland, Switzerland.

This introductory chapter describes what a wetland is, different types of wetlands, and their diversity and productivity. Economic value and ecosystem services are also briefly discussed. This is part of a publication from the Ramsar Convention on Wetlands.

Bao, T.Q. 2011. Effect of mangrove forest structures on wave attenuation in coastal Vietnam. Oceanologia 53:807-818.

Different mangrove plots from two distantly-located sites in Vietnam (one in northern Vietnam, one in southern Vietnam) were studied. Mangrove forest structure (thickness, height, etc.) attenuated waves as well as width of mangrove bands. A vegetation (V) index is used for forest structure and correlates with wave attenuation. The actual mechanism of wave attenuation is also discussed.

Barbier, E.B., I.Y. Georgiou, B. Enchelmeyer, and D.J. Reed. 2013. The value of wetlands in protecting southeast Louisiana from hurricane storm surges. PLoS ONE 8(3): e58715.

This paper corroborates previous research on the value of wetlands as storm buffers in coastal areas, concentrating on the coastal wetlands of southeast Louisiana and the greater New Orleans area. The authors found that even very small increases in wetland continuity led to measurable reductions in property damage from storm surges.

Costanza, R. 1994. Three general policies to achieve sustainability. pp 392-407 in: A. M. Jansson, M. Hammer, C. Folke, and R. Costanza (eds.), Investing in Natural Capital: The Ecological Economics Approach to Sustainability. Island Press, Washington, DC, 504 pp

This essay chapter outlines three very broad ideas for achieving sustainability. Namely, a tax system which incentivizes protection of 'natural capital,' introduces the 4P (precautionary polluter pays principle) model whereby the cost of products must include environmental costs, and the implementation of 'ecological tariffs' to keep companies from simply using foreign labor to skirt these laws. The idea of 'natural capital' and 'ecological economics' is also discussed at length, as are methods for dealing with scientific uncertainty.

Costanza R., R. d'Arge R., R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Sutton, and M. van den Belt. 1997. The value of the world's ecosystem services and natural capital. Nature 387:253-260.

An often-cited paper where 17 ecosystem services are analyzed over 16 biomes. Financial value in USD is discussed for each biome. Ecosystem services are estimated to be worth almost 2x global GNP. Wetland value is estimated to be greater than one-quarter of the United States' GNP. Ecosystem services are discussed at length and the term 'natural capital' is delineated.

Costanza, R., O. Pérez-Maqueo, M. L. Martinez, P. Sutton, S. J. Anderson, and K. Mulder. 2008. The value of coastal wetlands for hurricane protection. Ambio 37:241-248.

Coastal wetlands from Louisiana to Thailand are quite important at reducing damage from storms. In this paper, a regression model was used to look at 34 hurricanes and examine the extent of storm surge in relation to the amount of wetlands between the hurricane's landfall and populated areas. The authors argue that any time and money spent on wetland preservation or restoration has a very high ROI from money (and lives) saved in the aftermath of large storms that are likely to become more common under future climate regimes.

Costanza, R., W. J. Mitsch, and J. W. Day, Jr. 2006a. Creating a sustainable and desirable New Orleans. Ecological Engineering 26:317-320.

A shorter, somewhat parallel paper to 2006b. Explicit developmental concerns are addressed. The need for restoration of natural capital is discussed. Strategies for avoiding future wide-scale devastation as was seen with Katrina are offered.

Costanza, R., W. J. Mitsch, and J. W. Day, Jr. 2006b. A new vision for New Orleans and the Mississippi delta: applying ecological economics and ecological engineering. Frontiers in Ecology and the Environment 4:465-472.

The preservation of wetlands, which are lost at a rate of $65km^2$ per year, is critical in the long-term sustainable development of coastal areas like New Orleans. Increased severity and frequency of storms due to climate change are actually exacerbating coastal wetland degradation, meaning that without significant effort committed to preservation of existing and restoration of degraded wetlands, a significant positive feedback loop will occur. Without action, both coastal wetland losses and storm damage will rise rapidly. This action must concentration not only on the wetlands themselves, but also the inter-linked aquatic and terrestrial habitats. Negative impacts on the Mississippi river, for example, substantially affect coastal wetlands. This is a multi-faceted problem with economic, ecological, and humanitarian aspects: it will require people from all angles (city planners, developers, scientists, and citizens) to come together and implement smart, sustainable development to ensure economic success, human safety, property protection, and preservation of 'natural capital.'

Couvillion, B.R., J.A. Barras, G.D. Steyer, W. Sleavin, M. Fischer, H. Beck, N. Trahan, B. Griffin, Brad, and D. Heckman. 2011. Land area change in coastal Louisiana from 1932 to 2010: U.S. Geological Survey Scientific Investigations Map 3164, scale 1:265,000, 12 p. pamphlet.

The last 80-100 years of Louisiana coastal wetlands are discussed with special emphasis given to the period from 1985-2010. Changes in land area and wetland loss are examined along with management advice. The report analyzes 17 datasets.

Goodland, R. and J. Anhang. 2009. Livestock and climate change. World Watch Magazine 22:10-19.

This report can be considered a follow-up to the UN FAO report from 2006. However, the authors actually argue that the FAO report was too conservative in the environmental impacts it attributed to animal agriculture. Greenhouse gas emissions, land use, and water consumption are reviewed. Mitigation strategies and related economics are also discussed.

Kathiresan, K. and N. Rajendran. 2005. Coastal mangrove forests mitigated tsunami. Estuarine, Coastal, and Shelf Science. 65:601-606.

Examines the effect of mangrove forests and proximity to human settlements; correlates this with human death and property damage resulting from the 2004 tsunami. The authors make development suggestions, such as where to build new developments and identify certain plant species which are ideal for using as buffers.

Knutson, T.R. 2008. Global warming and hurricanes: an overview of current research results. Geophysical Fluid Dynamics Laboratory/NOAA: www.gfdl.noaa.gov/global-warming-and-hurricanes

A review paper which looks at expected changes in hurricane activity under future climate regimes as predicted by modeling, and also whether there is any evidence of current anthropogenically-induced alterations. Several graphs indicate that we are already seeing increased activity. A brief overview of climate modeling relating to hurricanes is offered.

Koneswaran, G. and D. Nierenberg. 2008. Global farm animal production and global warming: impacting and mitigating climate change. Environ Health Perspect 116:578-582.

Discusses the contribution of animal agriculture to anthropogenic greenhouse gas emissions. Includes brief review of climate change, other anthropogenic sources of emissions, examines alternative strategies in light of future projections. The authors suggest considering these issues with regard to discussion of legislation dealing with climate change or environmental issues.

Martinez, M. L., R. Costanza, and O. Pérez-Maqueo. 2011. Ecosystem services provided by Estuarine and Coastal Ecosystems: Storm protection as a Service from Estuarine and Coastal Ecosystems. Chapter in: Treatise on Estuarine and Coastal Science, E. Wolanski and D. S. McLusky (Eds). Volume 12. Ecological Economics of Estuaries and Coasts, M. van den Belt and R. Costanza (Eds). Elsevier, Amsterdam.

Large reference book that explores estuarine ecosystems, their geology, chemistry, ecology, threats and conservation issues, and management. Includes substantial reading on ecosystem services and an entire volume on the ecological economics of estuaries and coastal areas. This specific chapter focuses on the role of estuarine and coastal ecosystems in protecting human development and natural landscapes from storm surge and flooding.

Mitsch W.J. and J.G. Gosselink. 2007. Wetlands 4th edition. Wiley, New York.

This is the fourth edition of a widely-used, comprehensive textbook on wetlands. Includes basic concepts of wetland science as well as chapters on climate change, hydrology, ecosystem valuation, biogeochemistry, constructing artificial wetlands, as well as an array of international case studies. Includes numerous photographs of different types of wetlands from around the world.

Nicholls, R.J. 2004. Coastal flooding and wetland Loss in the 21st century: Changes under the SRES climate and socio-economic scenarios. Global Environmental Change 14:69-86.

Changes in flooding from storm surges and potential loss of coastal wetlands is considered via the HadCM3 climate models under four potential emission scenarios. Predictions about the number of people affected by future floods in coastal areas are presented along with commentary on addressing these issues.

Steinfeld H., P. Gerber, T. Wassenaar, V. Castel, M. Rosales, and C. de Haan. 2006. Livestock's Long Shadow: Environmental Issues and Options. Rome: Food and Agriculture Organization of the United Nations.

A widely-cited publication by the United Nations Food and Agriculture Organization which shed light onto animal agriculture as a major factor in anthropogenic greenhouse gas emissions as well as water and energy efficiency. The report looks at the entire "supply chain:" the animals, their feed, water, transportation etc. Relevant projected forecasts are included as well as mitigation strategies and policy ideas.

US EPA. 2012. Wetlands and people. http://water.epa.gov/type/wetlands/people.cfm

A comprehensive website with an array of information about wetland types, threats to wetlands, and especially how people rely on wetlands for resources and ecosystem services.

US EPA. 2010. Methane and nitrous oxide emissions from natural sources. (430-R-10-001)

A thorough examination of natural (i.e., non-anthropogenic) sources of two of the most potent greenhouse gases. In-depth descriptions of each natural type of emission is given, as is an introduction to the greenhouse effect and why methane and nitrous oxide are so potent. Emission and sequestration of greenhouse gases by wetlands is discussed.

US EPA 1993. Constructed wetlands for wastewater treatment and wildlife habitat: 17 case studies. (EPA832-R-93-005)

An introduction to constructed wetlands: how they are planned and developed, their advantages and disadvantages, and answers to frequently asked questions regarding constructed wetlands. Included are 17 detailed case studies from around the United States.