International Journal of Fisheries and Aquatic Studies 2017; 5(2): 498-508

E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.549
IJFAS 2017; 5(2): 498-508

www.fisheriesjournal.com
Received: 05-01-2017
Accepted: 06-02-2017

Negese Kebtieneh
Debre Tabor University, Biology Department, P O. Box 272, Debre Tabor, Ethiopia

Correspondence
Negese Kebtieneh
Debre Tabor University, Biology Department, P O. Box 272, Debre Tabor, Ethiopia

The impact of global climate change on wetlands

Negese Kebtieneh

Abstract
Wetlands exist in a transition zone between aquatic and terrestrial environments which can be altered by subtle changes in hydrology. Wetlands that are most likely to be affected by these and other potential changes (e. g., sea-level rise, increasing temperature, change in precipitation) associated with atmospheric carbon enrichment include permafrost wetlands, coastal and estuarine wetlands, peat lands, alpine wetlands, and prairie pothole wetlands. Potential impacts range from changes in community structure to changes in ecological function, and from extirpation to enhancement. Wetlands (particularly boreal peat-lands) play an important role in the global carbon cycle; generally sequestering carbon in the form of biomass, methane, dissolved organic material and organic sediment. Wetlands that are drained or partially dried can become a net source of methane and carbon dioxide to the atmosphere, serving as a positive biotic feedback to global warming.

Keywords: Climate change, wetlands, carbon cycle, dissolved organic matter and sea-level rising

1. Introduction

Wetlands such as freshwater, coastal, marine water wetlands are among the ecosystems which will be most affected by even small changes in climate and resulting changes in hydro logic regimes such as sea level rise and decreased surface and ground water levels in the West. Many wetlands will be destroyed; rare and endangered plants and animals will be threatened in others. Climate change factors which affect wetlands are increasing carbon dioxide, increasing precipitation, higher temperature, lengthening growing season of plants, increasing sea level raises, e t c [1]. Introducing wetlands can store the most significance amounts of carbons, carbon sequestering and also produce significant quantities of methane and their management practices help to protect carbon stores [2].

2. Freshwater Wetlands

Shallow freshwater wetlands are already stressed as ecological zones between aquatic and upland terrestrial ecosystems, making them particularly sensitive to changes in temperature and precipitation. Freshwater wetlands have been extensively altered by humans. More than half of the wetlands in the lower 48 states have been converted to other uses since the mid-1700s [3]. Many of those that have not been converted exist in a degraded condition because of the cumulative effects of altered flow regimes, removal of timber, and deterioration of water quality due to human development and encroachment [4]. Because freshwater wetlands provide many critical goods and services. They have become highly valued by large sectors of society; yet human activity still threatens these sensitive ecosystems.

Climate change is expected to further stress wetlands, because increasing temperatures will affect species growth and reproduction, and altered water regimes will change soil and vegetation conditions [5, 6]. Freshwater wetlands provide habitat for species that have adapted to widely varying soil moisture and chemical conditions. Purely wetland species are often habitat specialists that can survive where else on the landscape. Further, wildlife populations are increasingly using wetlands as refuges as humans modify other types of ecosystems [7].

For this and other reasons, wetlands are very important contributors to biodiversity and wildlife in most landscapes [8]. The driving force of wetland ecosystems is the hydrologic regime, because it regulates the "wetness" of the wetland. The patterns of water depth, and the duration, frequency, and seasonality of flooding together constitute a wetland's hydro period, which determines its vegetation composition, habitat for aquatic organisms, and other ecosystem characteristics. Viewing wetlands according to hydro period is perhaps the best way to consider potential effects of climate change.

A shorter hydro period under drier conditions will allow species that are not as tolerant of prolonged soil saturation and oxygen deprivation to invade. By contrast, a longer hydro period normally results in tree death and eventual replacement by aquatic plants.

Carbon dioxide enrichment has the potential to alter species composition in some wetland types, independently of hydrologic or temperature changes. Some groups of plants are more responsive to higher CO_2 concentrations than others because of fundamental physiological differences. Marshes on the Chesapeake Bay, where most relevant studies have taken place, show quite striking increases in photosynthesis when CO_2 levels are raised. These studies suggest that, over the long term, the more responsive plant species may eventually crowd out the less responsive ones. However, there are many caveats, not the least of which is the difficulty of scaling up from individual plant responses to whole ecosystem responses, where many variables other than just CO_2 are important. In addition, it is difficult to generalize about the effects of CO_2 on wetlands because of uncertainty about changes in other important factors such as water use efficiency, insect and fungal damage, and soil bacterial activity [9]. Therefore, broad-scale generalizations of the effect of CO_2 enrichment on wetland communities are not currently feasible [10].

Responses to CO_2 enrichment are further masked by human-caused enrichment by nitrogen and phosphorus. It is common for aggressive plants (including non-native invasive species) to dominate when excess nutrients are available. Indeed, in low-fertility sites such as bogs and some lake shorelines, nutrient enrichment is known to favor weedy, aggressive species that can out of compete than native dominant species as well as rare and endangered species [1]. In these settings, additional CO_2 enrichment may contribute to the loss of sensitive species and thus reduce regional plant biodiversity.

2.1 Effects of altered water regime

The vulnerability of wetlands to a drying climate depends, in large part, on the sources of their water supply. The dominant sources of water to wetlands are precipitation, surface flows, and groundwater discharge [11]. As a general rule, wetlands that are fed mainly by precipitation are the most likely to lose wetland characteristics in a drying climate. Groundwater-driven sites that have a large volume of available water stored in aquifers will have the greatest resistance to climate change [6].

Wetlands dominated by precipitation are already at the "dry end" of the spectrum of wetland types [6]. They tend to occur in flat landscapes with low soil drainage in humid climates. If the climate were to dry, these wetlands would contract, resulting in the loss of locally unique species such as orchids and insectivorous plants characteristic of acidic peat bogs. Peat-based wet lands would be especially hard-hit as the highly organic soils undergo oxidation and subsidence, thus altering drainage patterns, topography, and exposure to fire. In a more

Humid climate, precipitation dominated wetlands could expand, assuming no barriers from competing land uses. The hydro periods of many wetlands are driven by surface waters such as adjacent rivers and lakes.

Climate change that alters hydrologic regimes of rivers and lakes will have ecological impacts on these wetlands. For example, a reduction in the frequency or magnitude of high flows that inundate the floodplain would tend to dry out floodplain wetlands, isolate them from the adjacent stream or river, and replace wetland plant species with more terrestrially adapted species [12, 13].

Floodplain wetlands along rivers with a snowmelt hydrology may be particularly harmed, because peak flows from seasonal snowmelt may disappear (see earlier section on streams and rivers). Analogues of this effect are seen below dams on impounded rivers, where reservoirs store flood flows and thus "shave" downstream flood peaks, transforming floodplain forests to species adapted to drier conditions [13].

Lake Fringe wetlands also tend to be driven by surface water, responding to both seasonal and inter annual variations in lake water levels. Multiannual cycles cause the position of these types of wetlands to migrate back and forth across shallow shorelines [14].

Their susceptibility to climate change will depend largely on shoreline morphology. For example, deepening of water under a wetter climate would eliminate some wetland plant species, especially in areas where the shoreline is too steep to allow plants to become established. Lower water levels would require that plants become established further Lake Ward, but this could only happen if protective barrier beaches form along the shoreline. This is of particular importance for the Great Lakes, where lake levels might drop significantly under projected climate change [15].

Groundwater is the principal water supply for many wetlands. If climate becomes wetter, rising water tables will expand wetland areas and make existing wetlands even wetter. Under a drier climate, the opposite will occur. For example, declines in water tables in the prairie pothole region of the Dakotas will cause many seasonal wetlands that typically remain flooded well into the summer to dry out weeks earlier.

This is the most important region in North America for breeding waterfowl. Using models that calibrate waterfowl populations and pond numbers to the Palmer Drought Severity Index and general circulation models (GCMs), [16] predicted that breeding bird populations would be reduced to about 50 percent of present long-term average in response to reduced precipitation and temperature increases of up to 4°C.

Drawdown of water for human uses provides additional insight into the effects of a drier climate on groundwater-dominated wetlands. In the northern Tampa Bay area of Florida, peat-based cypress domes have dried out because of drawdown for human consumptive use. This has caused the peat to oxidize and collapse, resulting in more destructive fires, invasion of weedy upland plants, an abnormally high tree-fall [17].

Other factors come into play for wetlands in arid climates, most of which receive groundwater as their dominant source. For example, riparian cottonwood forests in the arid West have died as a result of groundwater pumping [18]. These human-induced changes, however, typically occur much more abruptly than those expected from a drier climate. Further, because many groundwater-supplied wetlands are supported by large aquifers, these wetland types may be affected less by climate change than wetlands supplied by precipitation and surface water [6]. However, if conditions become drier, there is likely to be increased human demand for groundwater [19], which could negatively affect these wetland types.

2.2 Changes in temperature

Extensive regions throughout boreal and arctic zones of Alaska and Canada are covered by wetlands made up of organic rich soils under lain with permafrost. The warming predicted for these regions will increase the depth at which the ground stays frozen (i.e., lower the permafrost table), resulting in drainage that will expose the peat to the atmosphere, thus increasing the rates of organic decomposition and the release of CO_2 and methane [20].

Given the probability of increased fire frequency and intensity that accompanies drier conditions; more peat will tend to burn under a warmer climate. Carbon dioxide and methane generated from these sources would stimulate a positive feedback to global warming [20]. Groundwater-dominated wetlands, or fens, are also an important habitat for many rare species of plants and animals. Because groundwater travels slowly through subsurface pathways, it is buffered from atmospheric temperature extremes. Thus, the thermal regimes of fens are much cooler in the summer and warmer in the winter than adjacent surface waters. Many fens support wetland plant and animal species that normally occur in abundance only much farther north, where summer water temperatures are cooler [21]. These species were probably once common in the southern end of their current ranges when the climate was cooler, but they are now isolated. Thus, a change in future climate that eventually warms ground waters will cause a loss of these species from the southern end of their ranges.

2.3 Plant and animal movements in a changing climate

The geographic distributions of plants and animals living in freshwater wetland ecosystems may shift in response to a changing climate. Because the types of wetlands defined above occur in all climates (except those dominated by precipitation), transformation to a warmer and drier (or wetter) climate in a particular region will produce conditions that already exist for wetlands in a similar climate at a different geographic location [22]. For example, silver maple/ash/elm forests of the upper Midwest could be replaced by cypress/tupelo swamps, currently limited to the Southeast and along the Mississippi Valley. Treeless tundra wetlands of the Alaska North Slope permafrost could be replaced by black spruce peat lands with discontinuous permafrost. In each case, colonization by wetland plants and animals could be determined by the addition of species that migrate to their more favorable climatic conditions elsewhere and the removal of species that become locally extinct because of changing environmental conditions.

Species that survive the changed conditions have traits that are suited to the new environment. To some extent these traits allow predictions of survival under future environmental conditions [1]. If all species had instantaneous dispersal powers in response to climate change, and enough was known about the tolerances of individual species, it might be possible to predict with great accuracy the responses of species to changing climate. However, such predictions are precluded by many confounding factors, including formidable barriers to migration (both natural and human-caused, such as dams and dikes), changes in the frequency and seasonality of fires, and modification of water quality. Species vary greatly in their abilities to disperse, so the success of plants and animals in colonizing suitable habitats under a changing climate will be highly variable. Many recently introduced, non-native species have expanded rapidly across the landscape, and analysis of their mode of colonization may allow insight into which native species may be best able to disperse successfully under a changing climate [24].

These invaders may be expected, however, to interfere with the gradual spread of indigenous wetland plants, because the invaders are able to rapidly expand their range and to monopolize available space and nutrients before indigenous plants can arrive [24]. Further, the proliferation of these exotic species is favored by human activities unrelated to climate change (e.g., altered hydrology, nutrient loading, and sedimentation). For some wetland species, geographic barriers are so formidable that they are unlikely to be overcome in the time frame projected for climate change. For example, the flora of alpine wetlands, restricted to the highest peaks in the continental United States, is particularly vulnerable, because an increase in temperature will eliminate species that require cold thermal regimes [25]. Coastal Ecosystems potential changes in temperature and hydrologic regimes projected to occur over the next 100 years will most likely lead to loss of coastal wetlands, deterioration of water quality, and disruptions in fisheries. Sea-level rise, sediment starvation, and changing species composition in coastal wetlands all threaten the sustainability and resilience of these systems [26]. Coastal wetlands and estuaries are among the most productive ecosystems on earth [26].

The high productivity of these systems is related to the inputs of freshwater and to the fluctuating water levels caused by the ocean tides. Freshwater inputs to estuaries deliver not only nutrients that support high production, but also large quantities of suspended sediments, which are critical to the accretion of wetland soils that allow plants to avoid permanent inundation by the sea. In addition, the mixing of freshwater and seawater in estuaries creates water circulation patterns that tend to retain nutrients, which further enhances coastal ecosystem productivity. Coastal wetlands support dense populations of animals, many of them migratory and of great commercial value. The movements of many migratory aquatic animals (e.g., crabs, fish) to deeper sea water are regulated by estuarine salinity, which changes as freshwater inflows mix with tidal salt water. Temperature conditions are also an important environmental cue for migration. Further, water temperature regulates many ecological processes and the distribution of many coastal wetland species.

3. Coastal Wetland

Coastal wetland ecosystems are also among the most altered and threatened natural systems [27]. Important impacts include increased nutrient loading leading eutrophication, direct loss through habitat destruction, changes in hydrology, introduction of toxic materials, and changes in species composition due to over-harvest and introduction of new species [28]. Most coastal wetland loss has been due to draining and filling. In some coastal states, such as California, almost all coastal wetlands have been lost. In the largest coastal ecosystem in the United States, the Mississippi Delta, restriction of river sediment input is largely responsible for the massive wetland loss. Coastal eutrophication is a growing problem because of increasing inputs of nutrients.

Coastal wetland plants thrive in a relatively harsh intertidal environment characterized by alternate flooding and draining of salt marshes with associated water logging of soils, depletion of oxygen, and production of natural toxins that inhibit plant growth. To cope with these harsh conditions, plants have a number of adaptations, including the production of aerial roots and submerged tissues that allow them to capture oxygen needed by the roots. But these adaptations are suitable only as long as the average water level remains relatively constant.

Accordingly, coastal wetlands exist within a fixed elevational range, where the frequency and duration of inundation by seawater are relatively constant [29]. Because plants become progressively more stressed and ultimately die if they are inundated for too long [30], an increase in water levels due to sea-level rise can severely stress the integrity of coastal wetland ecosystems.

Sea-level rise over the last several decades has reportedly led to salinity intrusion and wetland loss in a number of coastal areas around the world and in the United States, including Long Island [31] the mid-Atlantic region [32, 33], Chesapeake Bay [34], and the Mississippi Delta [35, 36, 37]. Since sea-level rise over the last century is two to nine times lower than the projected 20-90 centimeters of sea-level rise expected over the next 100 years [38], there is great concern for the potential loss of coastal wetlands in the United States and globally. The projected rise in sea levels under global climate change will certainly place these productive and important ecosystems under additional stress, with the very likely result of extensive dieback of plants residing in the current intertidal zone. For example, a 0.5 meter rise in sea level would inundate about 12,000 square kilometers (about 4,600 square miles) of coastal wetlands, most of which would likely be lost [38].

Global climate change and sea-level rise can influence coastal fisheries in a number of ways. Approximately 70 percent of the U.S. fisheries' catch is derived from estuarine-dependent species, and their young are therefore dependent on suitable habitat [39]. Rising sea levels that lead to destruction of coastal wetlands can have direct negative consequences for coastal fisheries [39].

More indirect effects could result from wetland loss that leads to shoreline erosion, which, by adding fine sediments to the water Column, would reduce water clarity and thus interfere with feeding ability. Many shellfish species also use coastal wetlands as an important habitat; therefore, they are vulnerable to wetland loss caused by sea- level rise.

Fish and shellfish species that use coastal wetlands as nursery habitat are also sensitive to temperature conditions. As climate warms, many species will be forced to shift their geographic rang of ward toward suitable thermal rearing environments for their young [39].

The continued production of coastal fisheries will then be partially dependent on these species finding coastal environments containing functional nursery habitats at the higher latitude. Juvenile shellfish and fish rely on environmental cues for migration out to the sea, and these cues might be masked by changes brought on by the direct and indirect consequences of climate change. For example, large changes in freshwater inputs could also alter salinity gradients and estuarine circulation patterns that are important cues for migratory fish and shellfish. Changes in coastal ocean circulation patterns caused by changes in fresh water inputs and temperature may lead to changes in the regional patterns and spatial distribution of production as well as variability in naturally fluctuating stocks such as herring and sardines.

Long-term changes in the frequency, intensity, timing, and distribution of strong storms would most likely alter the species composition of coastal marshes, as well as the rates of important ecosystem processes such as nutrient cycling and primary and secondary productivity [22]. For coastal systems of the southeastern United States, there could be both positive and negative effects. For example, hurricanes greatly increase the rate of soil accretion in marshes, thereby helping to offset accelerated sea-level rise [41].

Runoff generated by hurricanes introduce freshwater and nutrients that can enhance coastal wetland productivity [42]. In the arid areas of south Texas, freshwater input can also have a stimulatory impact by reducing salinity and its attendant stresses [42]. On the negative side, hurricanes can reduce the structural complexity of coastal forested wetlands such as mangroves and tidal freshwater forested wetlands [43, 44].

The locations with the highest probability of hurricane landfall are south Florida and the Mississippi Delta. The coastal ecosystems of south Florida are dominated by mangroves and, if warming continues, the Mississippi Delta will become increasingly dominated by mangroves. This trend, combined with increased hurricane frequency, would reduce the structure of these forests and destroy some of them.

Freshwater forested wetlands (swamps) of the Mississippi Delta are slowly degrading and disappearing because increased flooding from rising water levels has largely eliminated the establishment and growth of young trees. Hurricanes can also cause tree loss; for example, [43] reported that nearly 10 per cent of trees in a swamp forest in Louisiana were blown down during the passage of Hurricane Andrew in 1992. An increase in hurricanes would amplify the kind of damage resulting from the interaction between rising water levels and hurricanes and would hasten the loss of forests in the Mississippi Delta and elsewhere. High runoff from hurricanes can also lead to excessive nutrient load in Carolina led to water quality problems and eutrophication problems.

4. Global climate change factors that affect wetlands

Carbon dioxide has increased 30% since pre-industrial times [20]. A doubling is anticipated by 2100 [45]. And Increase in air, water, and soil temperatures. Over the past century the global mean surface temperature has raised 0.5-1.1^{0}F [45]. The Intergovernmental Panel on Climate Change (IPCC) has estimated that global surface air temperatures will increase another 2-8F in the next hundred years with a "best guess" increase of 3.5 degrees by 2100. The most significant increases will occur in the northern latitudes. The temperature of wetlands, lakes, streams, rivers, estuaries, oceans, and ground waters will also, consequently, increase. There will be more "ice off" days of lakes and streams and a warming of the soils in northern latitudes These changes will be the most rapid increase in temperatures at any time in the last 100,000 years, challenging the adaptive capabilities of temperature sensitive wetland plants and animals which will often be unable to migrate northward due to the rapidity of the climate change or the fragmentation in systems [20].

Pursuant to various climate change models, it is estimated that overall, precipitation will increase in the U.S., but not for all areas. For example, somewhat decreased precipitation may be expected in the Southwest while increased precipitation will occur in the Southeast1. In addition, ground and surface water levels can be expected to fall in the Midwest and northern states despite somewhat increased precipitation if evaporation and rise sharply due to temperature increases. Higher temperatures and "speeding up" the water cycle will likely result in more severe climatologically events such as hurricanes, tornadoes, thunderstorms, and winter storms affecting wetland systems. It may also increase the intensity of severe precipitation events (heavy downpours of more than two inches per day). It has been estimated that the frequency of such severe events has increased by 20 percent in the U.S.

since the beginning of the century. Severe climatologically events such as intense rainfall in a region are likely to bring more sediment into some wetlands (e.g. Alluvial, estuarine) while increasing erosion in others (down cutting of sediment-starved streams in floodplains, coastal and estuarine erosion).

Lengthened growing season in northern latitude based on satellite imagery, it estimated that the growing season in northern latitudes (between 45 degrees and 70 degrees north) has increased by a total of twelve days. More increases are expected. And sea level rise, the IPCC phase estimated that by 2100 sea level is expected to rise 0.09 to 0.88 meters due to thermal expansion of ocean water and melting of glaciers and ice caps [29]. Globally, relative sea level has been 4 to 10 inches over the last 100 years. Other changes with possible significance to wetland ecosystems are also occurring such as an increase in atmospheric methane and a decrease in ozone with increased infrared exposure.

Fig 1. Erosion due to storm wave

4.1 The impacts of these climate change factors on wetlands

Increased CO_2 will increase the primary productivity of most wetland plants except were sunlight, precipitation or temperature is a limiting factor. Increase in primary productivity would enhance the habitat value of some wetlands. Although, some shift in plant and animal species might also be expected and variations in responses. There are indications that this increased productivity will also result in increased methane emissions. The natural ranges of both natural and invasive wetland plant species that are killed by frost such as mangroves and Melaleuca in Florida will be extended northward and upslope in mountainous areas. So will the ranges of temperature sensitive animals and insects such as fish and mosquitoes including various disease vectors (e.g., mosquitoes [30].

Increases in temperatures combined with reductions in precipitation will likely reduce surface and ground water levels in northern latitude wetlands, destroying or reducing in size many wetlands. Lowered water levels will result in release of carbon and methane. Decreased precipitation in some areas (e.g., the Southwest) will reduce runoff and water tables. This will reduce freshwater wetland size and will convert some wetlands to dry land. Such a result is particularly likely for forested, shrub, fresh meadow, and other shallow water or high ground water wetlands which are particularly sensitive to small hydrologic changes. It will also affect temporary and seasonal wetlands. Some of these areas can be converted to upland by lowered water tables of only a few inches [48].

Decreased precipitation may also result in reduced river flows and increased impoundment of waters with subsequent saltwater intrusion into estuary areas and estuarine wetlands. And also increased precipitation in some areas such as the Southeast [48] will result in increased ground water levels and increased water levels in wetlands and lakes.

This is likely to further result in an increase in size of some freshwater wetlands (lake fringe, riverine fringe, depress ional, flat, slope) due to the inundation or saturation of new fringe areas, an increase in the number of depress ional, flats, lake fringe, riverine, and slope wetlands (i.e., some will appear where they have not been before). A shift in wetland type and associated vegetation and fauna in some instances from saturated soil and shallow water fresh meadows and shrub/scrub or forested wetlands to marsh and open water types. This will favor fish species and waterfowl requiring open water. All wetland systems are, to a greater or lesser extent, already subject to disturbance by extreme rainfall, flooding, and high winds. Under natural conditions, wetland vegetation and animals may suffer temporary damage such as toppling of trees and some loss of wildlife. But, most of the damage from such events is temporary. Projected sea level rises of .09 to .88 meters by 2100 combined with coastal subsidence in some areas will likely have severe impact on coastal and estuarine wetlands, particularly on the Atlantic and Gulf coasts [30].

There will be wetland losses where there is insufficient plant growth and sediment deposition to equal sea level rise and coastal or estuarine wetlands cannot migrate inland. This is a particular problem for deltaic systems such as the Mississippi Delta where sediment-trapping reservoirs have been constructed along inflowing rivers and subsidence is occurring due to compaction of sediments, oil and gas removal, and is static adjustments. Loss of many of these wetlands can be expected with some return of the carbon contained in the peats and soils to the atmosphere [49]. In other instances; the carbon will be redeposit in new marshes or transported to the open ocean. Rapid, substantial changes in sea level pose significant threats to coastal and estuarine wetlands where back-lying lands are developed and sediment regimes have been disturbed. Sea levels could rise .09 to .88 meters by year 2100. A one meter in sea level rise would inundate twenty thousand square kilometers (sever thousand square miles) of dry land in the United States—about the size of Massachusetts. Mangroves and marsh ecosystems can remain viable despite sea level rise due to accumulation of organic matter and sediments at the present 1-3mm rate of sea level rise per year. However, accelerated future rates in sea level rise will likely result in a shift in species composition, decreased marsh productivity (plant biomasses), and marsh destruction.

Coastal and estuarine wetlands will be submerged and destroyed where they are unable to either migrate inland or grow upward through deposition of organic matter and sediment. Not only coastal and estuarine wetlands but community composition and aerial extent of communities of submerged aquatic vegetation (e.g., sea grasses) may be affected by increased water depths, increased storm disturbances, reduce light penetration, and changing salinities. Temperature rise of 2-9 degrees F may significantly impact some wetland flora and fauna with northerly shifts in vegetation and animal species where adequate migration pathways and time for such migration [31]. Other species (e.g., endangered plants and animals) may be destroyed or their

numbers seriously reduced by rapid shifts in temperature and/or precipitation. Increased air, water and soil temperatures could have both direct and indirect impacts upon wetland plants (e.g., temperate forests) and animals (e.g., cold water fish).
And also increase in mean annual temperatures and resulting increases in water temperatures may result in destruction of wetland rare and endangered plant and animal species with sensitivity to small temperature changes and no alternative, nearby habitat [32]. This is particularly true for mountain and alpine communities and species near the peaks of mountains and unable to move or disperse to higher elevations. Temperature increases will cause northerly and upslope shifts in ranges for wetland trees (e.g., temperate forests) and other plant and animals with narrow water temperature tolerances (e.g., trout). Because of the sensitivity of many plants to temperature changes, the growth capabilities of specific plants may be moved 200 to 300 km north for each degree centigrade increase in temperature and about 60 to 90 miles for each degree Fahrenheit.
The IPCC concluded more generally that the "composition and geographic distribution of many ecosystems...will shift as individual species respond to changes in climate, there will likely be reductions in biological diversity and in the goods and services that ecosystems provide." Under natural, unfragmented conditions, many species would migrate north or upslope on mountains with rising temperatures. But, this will be impossible or difficult where such migrations are hindered by dams, fills, or other impediments.
Temperature increases will likely result in the melt permafrost, increase decomposition rates, and releasing carbon dioxide and changing methane and nitrous oxide emissions and creating open water wetlands or aquatic ecosystems. There will also be significant indirect effects of temperature, evaporation, and transpiration increases. These will like result in less runoff (un compensated by increase rainfall), less infiltration, and lowered ground water levels.

Fig 2. Increased temperature will increase evaporation, drying, and many wetlands

4.2 The impacts on wetlands more severe than impacts on upland systems

Wetland ecosystems will be more severely impacted by climate change [33] in comparison to many terrestrial ecosystems. For three several reasons. Flora and fauna in wetlands are especially sensitive to small, permanent changes in water levels while similar small changes in water levels often have less impact upon rivers, streams, and lakes. For example, lower long-term, mean water levels even a few inches in a wetland can make the difference between a forested, shrub, or "fresh meadow" or a wetland and dry ground. A similar drop in water levels will usually have more limited impact on lakes, rivers and other aquatic ecosystems [34].
Wetlands have often been fragmented and cut off hydro logically and ecologically from other wetlands and aquatic ecosystems by dams, dikes, fills, roads, drainage, and other landscape level alterations. Due to this fragmentation, wetland plants and animals cannot naturally "migrate" to other locations over time in response to temperature and water level changes. Similarly, many coastal or estuarine wetlands will be unable to move inland in response to sea level rise, due to construction of dikes, levees, fills, or other development which fix the landward boundary [35].
Many wetlands are already severely stressed due to hydrologic changes, water pollution, changes in sediment regimes, and other activities of mankind. These stresses have lowered biodiversity in wetlands. Reduced numbers of types of plants and animals makes the wetlands more vulnerable to small changes in temperature and water regimes. Impacts will vary depending upon the types, magnitudes, and rate of changes in temperature, precipitation, hydro period, and other factors and the plant and animal species in a wetland [33].
Each plant species (and there are more than 6,000 listed wetland plants alone) may respond somewhat differently although certain general responses may be expected. For example, increased CO_2 may be expected to increase plant growth overall but this will not necessarily be true for all plant species and contexts with a broad range of limiting factors on growth such as nitrogen and suitable substrate. Similarly, a combination of increased temperature and constant or reduced precipitation will likely result in decreased runoff and lowered ground water levels, causing the drying of some wetlands and a decrease in size or change in wetland types for some others. But, this result is less likely for wetlands adjacent to large water bodies.

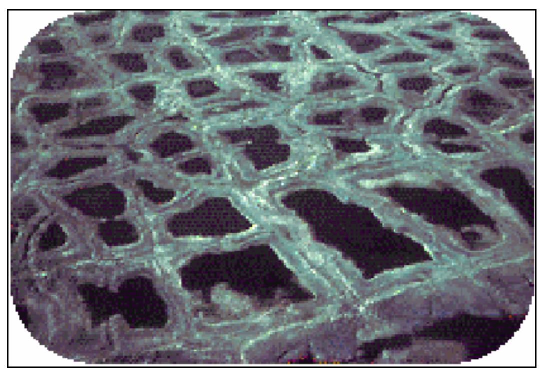

Fig 3: Increased temperatures will melt permafrost

4.3 The types of wetlands that are mostly affected by climate change

Wetland types likely to be substantially impacted by climate change. As already discussed, coastal and estuarine wetlands may be destroyed if sea level rise exceeds the rate of deposition and inland migration is not possible. For example, a two-foot rise in the Everglades would move the land/sea boundary several kilometers inland. In salt marshes there will be a change in terms of species composition or vegetation types [34].
Submerged aquatic vegetation, coastal marshes, mangroves, bald cypress swamps, coastal bottomland hardwood forests, and other wetland types may all be affected [32]. And areas of permafrost wetland may be melted and converted to open water by temperature increases. Water levels in other open

peat lands may fall due to rising temperatures. Carbon dioxide releases and possibly methane releases from methane hydrates may result. Open tundra may be invaded by boreal forests. Climate change is likely to have significant impact upon boreal forests through the loss of southern boreal forests, invasion of northern tree lines into tundra areas, increased fire, and increased pest outbreaks [34].

A combination of temperature increase and the lowering of ground water tables may expose peat and organic soils to oxidation. However, increases in carbon dioxide may also result in increased forest vegetation. Even small amounts of warming may destroy “relic” plant and animal species in alpine wetlands since there will be little opportunity to migrate to other locations [34]. Reductions in wetland size and the disappearance of some wetlands can be expected with substantial increases in temperatures and only modest increases in precipitation in the Prairie Pothole region [36]. Waterfowl production may be reduced by the reduced precipitation in the spring or fall and reduced water levels when migrations occur even if overall precipitation levels do no change. Temporary, shallow wetlands will be particularly sensitive to increases in temperatures and increased evaporation and transpiration. They will also be sensitive to decreases or increases in precipitation [36]. Other depresses zonal, slope, flats, river and lake fringe wetlands. Some drying, decrease in wetland size, and conversion to uplands can be expected for most freshwater wetlands where precipitation is decreased or remains steady while temperatures are substantially increased since these wetlands are very sensitive to small changes in ground water levels [34].

However, there may be exceptions such as the Great Lakes where lowering of water levels may expose wide flats or benches which will be colonized by wetland vegetation. On the other hand, some reverine, lake fringe, and other wetlands in regions of the nation with increased rainfall such as the Southeast will increase in size and vegetation density may increase in wetlands overall due to rising CO_2 levels. Increased size of coastal wetlands is unlikely where shorelines have been “hardened” by bulkheads or other structures [34].

4.4 Wetland functions mostly affected by climate change

The impact of climate change on the services and goods wetlands provide for society will vary by type of wetland and by function/value. With rising water temperatures in lakes, streams and wetlands, reduction in the numbers of cold water fish (e.g., trout) and increase in warm water fish such as bass may be expected. With rapid sea level rise and destruction of salt marshes which cannot migrate inland, reduced yields of ocean and estuarine fish species which depend upon coastal and estuarine wetlands for rearing or food chain support may also be expected [49] and reduction in the size of coastal and estuarine wetlands and adjacent “flats” and increases in water depths will reduce shellfish production. Increased temperatures with only slightly increased precipitation in the prairie pothole region will convert some wetlands to dry land, reduce others in size, and shift marshes with standing water to saturated soil wetland types (e.g., shrub or forested wetlands). Changed water regimes during the spring and fall may adversely affect waterfowl even if precipitation remains constant [49].

The role of wetlands throughout the Nation as habitat for rare and endangered species may be compromised wherever species are dependent upon specific hydrologic and temperature conditions and flora and fauna cannot migrate to new locations. This is particularly true for systems that are already stressed by water pollution and human-induced alterations and are highly fragmented. Species extinctions and biodiversity loss are probable; species range and ecosystem structure will also change. Further damage due to invasions by exotic species with northward extension of ranges. Destruction of coastal and estuarine wetlands by rapid sea level rise would reservoirs loss of detritus and other food chain support for estuarine and coastal fish, shellfish, and other fauna [37].

Destruction of coastal and estuarine wetlands due to sea level rise would result in loss of their water quality pollution control functions. Similar losses would occur where depress ional, slope, flats, and river and lake fringe wetlands are diminished in size or destroyed by lowered ground or surface water elevations due to reduced precipitation and/or increased temperatures. On the other hand, some increase in water quality buffering could occur for freshwater wetlands due to CO_2 induced increases in the density and amounts of vegetation (assuming adequate water levels to maintain wetlands and lack of other limiting factors) [37].

Some wetlands would increase in size and numbers in areas of increased rainfall. The destruction of coastal and estuarine wetlands by sea level rise would expose back-lying lands to added force from hurricanes and winter storm winds and waves [59]. However, the increased density of wetland trees and other vegetation due to increased CO_2 might also enhance the wave attenuation and erosion control functions of surviving estuarine, coastal, and freshwater wetlands.

Increased CO_2 will result in increased growth of trees and other natural wetland crops such as wild rice, and cranberries if such increases are not “limited” by phosphorus, nitrogen, or other limiting factors. Nevertheless, there could also be loss of coastal, estuarine, and freshwater wetlands and the forestry products they produce by sea level rise, increased severe meteorological events, and decreased precipitation in some instances. For example, bottomland hardwoods are particularly susceptible to hurricanes. Through, Increased CO2 could result in increased; plant growth in wetlands and the potential for increased carbon sequestration where there are not other limiting factors [39]. But, the carbon storage and sequestering role of tundra wetlands could also be reduced by the melting of permafrost, drainage (in some instances) and the subsequent release of carbon dioxide and other atmospheric gases. Carbon storage and sequestering by northern, non-permafrost peat lands would also likely be reduced by a combination of increased temperatures and reduced ground and surface water levels, causing oxidation of the peat [39].

Fig 4: Alpine wetlands could be affected by global warming

4.5 Land and water management practices adopted to reduce the impacts of climate change on wetlands

There is no practical option to protect the very large numbers of wetlands as a whole in the U.S. (e.g., over 25 million Prairie Pothole wetlands alone) from increased temperatures, decreased precipitation, or rising sea levels short of controlling climate change through limits on emissions of carbon dioxide and other greenhouse gases [40]. However, the federal government, states, local governments, and the private sectors (e.g. duck clubs, The Nature Conservancy) could selectively apply management measures [40] to specific wetlands on a wetland-by-wetland basis to increase the resiliency of wetland systems or to reduce or partially compensate for impacts. General strategies for reducing the impacts of climate change and achieving to the goal. There will be no way to protect objectives including protection of carbon millions of Prairie Potholes stores.

With an existing, limited number of wetlands remaining to provide services and goods to society (flood conveyance, flood storage, pollution control, fish production, etc.) estimated to be less than 50% of former acreage and the prospect of more diminished numbers and sizes of wetlands from a broad range of causes, it makes good sense to better protect existing wetlands from drainage or filling or drainage through regulations, plans, acquisition, and other technique [41]. This is true even if significant climate changes do not occur. With the possibility of climate change, it would be particularly important to protect types of wetlands (e.g. coastal, estuarine) which provide essential services (e.g., food chain support, fisheries, shellfish) and which could be further reduced in size or number or otherwise adversely affected by climate change.

For the same reasons, make good sense to better control air and water pollution, vegetation removal, and invasion of exotics, grazing by livestock and other stresses upon existing wetlands [41]. Stresses reduce existing wetland functions and the numbers and types of wetland plant and animal species. With reduced biodiversity and resiliency, wetlands are also more susceptible to climate change. Efforts to prevent fragmentation of wetlands and related floodplain, riparian, and aquatic ecosystems by dams, dikes, levees, fills, and upland activities are needed to protect existing wetland functions and values such as flood conveyance, fisheries, and water quality protection [42]. Prevention of fragmentation becomes even more important to permit the migration of flora and fauna in response to climate change induced temperature changes and to permit animals to find refuge during floods. On the other hand, fragmentation may also reduce (in some instances) invasion by exotic species.

Efforts to create wetland, floodplain, and riparian buffers can help protect existing tidal and freshwater wetlands by reducing pollution and sediment loading upon wetlands, providing food chain support, and providing habitat for species such as song birds, deer, and amphibians, that use wetlands only a portion of the time. Upland buffers will be even more important for coastal and estuarine wetlands. If sea levels rise due to climate change because such buffers would provide room for wetlands to "migrate". Upland buffers would similarly give freshwater wetlands in the Southeast and other areas subject to increased rainfall room to increase in size.

Efforts to control exotic species in wetlands can protect wetland functions such as providing fish or waterfowl habitat under existing conditions. Control will be even more important with climate change and the northward migration of certain exotics. However, measures to control exotics (e.g., isolation of wetlands from other water bodies) may also reduce the migration of desirable species [42]. Efforts by fish and wildlife agencies and environmental organizations to protect the low flows of rivers and other water bodies during hot summer months or droughts through "appropriation" of low flow water rights, adoption of regulations or other techniques can serve a broad range of goals under existing conditions. Protection of low flows and other residual water is needed to maintain oxygen levels and to protect fish, amphibians, and other aquatic organisms. Such efforts will be even more important for areas with increased temperatures and decreased precipitation caused by climate change. Control of extraction of peat can help protect habitat and other wetland functions as well as protect carbon stores. Twenty-three states produced about 900,000 tons of peat worth about $20 million in 1988.

Most peat was for soil conditioning and potting soil. Wetland restoration and creation can, under existing conditions, help compensate for existing loss of wetland functions (flood storage, flood conveyance, water quality buffering) [43]. Such efforts may also be able to reduce the impacts of climate change. This is particularly true if restoration or creation includes design features that allow for adaptive management. For example, inclusion of water control structures in the design of restoration and creation projects allows water level manipulation in the event of summer temperature increases or reduced precipitation.

Stocking of wetlands and related water bodies with fish can help replenish stocks depleted by stresses under existing conditions such as water pollution, invasion of exotic predators (e.g., lamprey), or over harvesting. Captive breeding programs for other wildlife species can also supplement natural stocks and prevent extinctions. For example, the International Crane Foundation maintains an active captive-breeding program for rare cranes in Baraboo, Wisconsin. In the event of climate change, broader stocking and captive breeding programs may also be used to bolster depleted populations or to move species to northward wetlands and water bodies as water temperatures and vegetation change [44].

And also Regional inventories of wetlands at risk could help regulatory, acquisition, and other management efforts. Such inventories could include designation of protection, acquisition, and restoration priorities based upon anticipated climate changes. For example, a plan might recommend acquisition of deeper, open water wetlands in a prairie pothole area where significant increases in temperature and decreases in precipitation are expected. Deeper water areas would convert to marshes under such conditions, partially offsetting the loss of shallow marshes needed for waterfowl feeding and nesting. These strategies could be combined regionally and for individual wetlands. Many but not all of these would be "no risk" or "low risk" options and justified under existing conditions as well [40]

4.6 Wetlands contain large stores of carbon

There is a significant amount of carbon stored in wetland soils, pleats, litter, and vegetation in the U.S [44] and globally (estimated 500-700 GT globally). Globally, the amount stored in wetlands may approach the total amount of atmospheric carbon (estimated at 753 GT). However, total carbon stored in wetlands in the U.S. is uncertain because no comprehensive inventory of wetland soil carbon has been done in the U.S. and most quantitative measurements of soil and peat carbon and carbon and methane fluxes to date has focused on boreal peat lands and rice paddies in other countries [44].

Most measurements have been in the upper meter of soil or peat and few studies have considered the full depth of wetland organic soils. Peat lands are found in some areas of the U.S. (Minnesota, Alaska). There is a relatively small acreage of rice paddies. Wetlands such slope wetlands, depress ional wetlands, coastal and estuarine salt marshes, Lake Fringe wetlands, and riverine wetlands [57]. Particularly large amounts of carbon may be broadly dispersed in the thick sediments of deltaic and riverine wetlands.

Fig 5: Floodplain alluvium may contain large amounts of carbon.

4.6.1 Wetlands store carbon from sources throughout watersheds.

Wetlands may also be more important than formerly believed as sinks of carbon produced from upland agriculture, forestry, and other land uses [45] and not simply carbon fixed by photosynthesis within wetlands. Carbon from watershed sources in the form of soil organic carbon, leaves, tree trunks (major floods), and other materials is washed into low lying wetland areas throughout the landscape and deposited at the toes of slopes of hills and mountains (slope wetlands), in depressions in agricultural landscapes (depress ional wetlands like the Prairie Potholes), in lake fringe wetlands along the Great Lakes and tens of thousands of smaller lakes, in riverine and floodplain wetlands along major rivers like the Mississippi, and in coastal and estuarine wetlands like the Mississippi Delta where total sedimentary deposition has been enormous (tens of thousands of feet) [46].

Some, but not all of the carbon deposited in these wetlands is recycled to the atmosphere by aerobic and anaerobic decomposition. But even this decomposition takes considerable time and a portion may be stored for hundreds, thousands of years, or longer. By acting as sinks and storing carbon produced throughout wetland drainage areas, wetlands may magnify the importance of carbon sequestering by upland agriculture and forestry activities. Loss of carbon from upland agricultural and forestry sites through erosion and surface water transport to wetlands does not necessarily mean loss to the atmosphere [45].

4.6.2 Types of wetlands that contain the most significant carbon stores

Peat lands contain the most carbon. However, coastal wetlands, prairie potholes, river and lake fringing wetlands and other wetland types may also contain significant amounts of carbon [46]. Wetlands continue to sequester carbon; Peat lands in the Northern U.S. (Minnesota, Maine) and Alaska continue to sequester small quantities of carbon. Other types of wetlands may also sequester modest amounts of carbon as a result of plant growth within Peat lands contain particularly wetlands and by acting as sinks for large organic deposit of carbon and sediment generated throughout the landscape as discussed above.

The release of carbon may exceed sequestering if temperatures rise due to climate change. This is particularly true if water levels fall. Even more of the carbon stored in wetlands in the U.S. and globally will be released if wetlands continue to be drained. Upon drainage bacteria which live in aerated conditions will oxidize much of the carbon and return it to the atmosphere [47]. Serious subsidence may then occur in some areas (e.g., the Sacramento Delta, the Everglades). Release and sequestration will depend upon atmospheric carbon dioxide levels, temperature, water levels, fires, harvesting, and land management practices. Fires may accelerate this release. Increased CO_2 and increased temperatures may increase photosynthesis and sequestering in some circumstances. However, increased temperatures will also increase decomposition and evapotranspiration leading to lowered water levels in some instances. Lowered water levels will lead to increased oxidation and return of carbon to the atmosphere.

4.6.3 Wetland management practices help protect carbon stores

A variety of practices can help protect existing carbon stores and the ability of wetlands to sequester carbon [47]. Examples include: Control drainage and other land and water management, practices which lead to dewatering of wetlands and oxidation, control fires including deep burns, allow natural re vegetation to occur, control peat harvesting and other removal of carbon from wetlands [48].

Fig 6: Increased temperatures and decreased precipitation will result in more fires and release of carbon

4.6.4 Wetlands produce significant quantities of methane

Total emissions from wetlands have been estimated to be in the 15-22% range of total global methane emissions [50]. Most of these emissions are at lower latitudes rather than in the U.S., for example the Amazon floodplain. Because methane is a very active greenhouse gas, the climate change forcing function of methane from some types of wetlands may exceed the function of carbon sequestering, particularly on short term basis [51]. However, methane emission rates have been measured primarily for Peat lands and rice paddies [52].

Methane emissions are lower for coastal and estuarine wetlands, pocasins, playas, and some other wetland types and methane breaks down rather quickly in the atmosphere (10-17 years) while carbon storage in wetlands may take place for very long periods. In the long term (500-1000) years methane has a decreasing affects [52]. Climate change affects methane production; Methane production depends upon water levels, temperature, and water chemistry [52]. Increased temperatures and precipitation at some latitudes will increase methane production. Wetland creation, restoration, or enhancement used to increase carbon sequestering and reduce methane emissions [81]. In some instances. For example, water control structures could be used to increase the duration of saturation. However, in many other instances carbon storage will be a "value added" reason to protect and restore along with protection or restoration of plant and animal species, pollution control, flood storage, etc. However, creation, restoration, and enhancement may also result in increased methane production depending upon the design and management [43].

Sufficient scientific basis to change wetland management practices to protect wetlands from climate change and protect carbon stores [48]. This is particularly true where changes may be undertaken at modest cost and serve multiple additional objectives. For example, better controlling wetland drainage will not only improve the resilience these wetlands to climate change but protect carbon stores, biodiversity, food chain support, flood storage and conveyance, and a host of other functions/values. Providing buffers to allow migration of estuarine wetland will serve multiple objectives in addition to reducing the impacts of climate change including protection of wave retardation and erosion control, protection of Setbacks can provide room estuaries from pollution, and coastal/estuarine wetlands to move inland protection of fish and shellfish spawning areas [49].

5. Conclusion

Fresh water wetlands are already stressed as economic zones between aquatic and upland terrestrial ecosystem aquatic and particularly sensitive to changes in temperature and precipitation. It also further affected increase sea level raises, altered water regimes, the change in soil moisture and chemical conditions, hydrologic regime. These leads the plant and animal movements in a changing climate.

Coastal wetlands are also among the most altered and threaded nutrient loading or etrophication, direct loss through habitat destruction, changes in hydrology, over harvesting and sea level raises. Factors that affect wetlands, their impacts, the impacts of wetland more severe than impacts on up land systems the types of wetlands that are mostly affected by climate change their functions and also land and water management adopted to reduce the impacts of climate change on wetlands. They contain large amount of carbon, their carbon sequencing and produced significant quantities of methane. There contribute of the impacts by increasing global climate change on wetland ecosystem.

6. Acknowledgment

I would like to acknowledge the assistance i received form the following. My first and sincere appreciation goes to Dr. Grima Tilahun for this valuable comments and feedback in each and every step to bring this paper to final stage. I would not forget to express my heartily appreciate to Department of Biology for giving encouragement and appreciation during review.

7. References

1. Keddy PA. Appragmatic Approch to functional Ecology, 1992.
2. Bartlett KB, Harris RC. Review and Assessment of Methane Emissions from Wetlands. Chemosphere 1993; 26:261-320.
3. Boesch DF, Josselyn AJ, Mehta AD. Scientific Assessment of Coastal Wetland Loss, Restoration, and Management in Louisiana. Journal of Coastal Research, Special Issue No. 1994, 20,
4. Chan M. Forbes S. Carbon Sequestration Role in State and Local Actions 2005.
5. Dean W, Gorham E. Magnitude and Significance of Carbon Burial in Lakes, Reservoirs and Peat lands, 1998.
6. Winter TC. The vulnerability of wetlands to climate change, 2000.
7. Calhoun A. Forested wetlands maintaining biodiversity in forest ecosystems. 1999.
8. Brinson MM, Verhoeven. Riparian foresters in maintaining Biodiversity in forest ecosystem, 1993.
9. Thompson GB. Drake BG. Insects and Fungi on C_3 sedge and C_4 grass exposed to Elevated atmospheric carbon dioxide concentration in open tap chambers in field, 1994.
10. Marsh AS. How wetland plants respond to elevated carbon dioxide. Masschelein 1999. http://www.ecology and society.org/vol2/iss1/art1/ J.
11. Brinson MM. Gradients in function of wetlands along environmental gradient, 1993.
12. Johnson WC, Keammerer WR. Forest over story vegetation on the missouri river, Flood plain in North Dakota, 1997.
13. Nicholls R. Hoozemans F, Marchand M. Increasing Flood Risk and Wetland Losses Due to Global Sea-level Rise Patterson, J. Wetlands and Climate Change, 1999.
14. Patterson J, Kusler J. Peat lands and the Climate Challenge, 1999.
15. Roulet N. Peatlands, Carbon Storage, Greenhouse Gases, and the Kyoto: Prospects and significance for Canada. Wetlands. 2000; 20(4):605-709.
16. Schindler D. Effects of Climatic Warming on Lakes of the Central Boreal Forest. Science. 1990, 250.
17. Rochow TF. The Effect water table level changes on fresh water march and cypress wetlands in north Tampa Bay Region, 1994.
18. Scatt MC, Shafroth PB, Auble GT. Response of riparian cotton woods to Alluvial water able Declines. 1999.
19. Frederick KD, Gleick PH. Water and global climate change, 1999.
20. Gorham E. The Biogeochemistry of Northern Peatlands and Its Possible Response to Global Warming, Biotic Processes and Potential Feedbacks, 1991.
21. Cooper DJ. Water and soil chemistry, 1996.
22. Michener WK, Blood ER, Bilstein KL. Climate Change, Hurricanes and Tropical Storms, and Rising Sea Level in Coastal Wetlands. 1997.
23. Kimble RJ. Birsey R. Potential of U.S. Forest Soils to Sequester Carbon and Mitigate the Greenhouse Effect, 2002.
24. Galtowitsch SM, Anderson ON. Ascher PD. Invasvinaces in Wetland plants in tempre in North American, 1999.
25. Halpin PN. Global climate change on natural area protection, Management response and Research direction, 1997.
26. Day JW, Template. Consequences of sea level rise, 1989.
27. Finlayson M. Coastal Wetlands and Climate Change: the Role of Governance and Science. Aquatic conservation:

marine and freshwater ecosystems. 1999; 9:621-626.
28. Schindler D. A Dim Future for Boreal Watershed Landscapes. Bio Science. 1998; 48:157-164.
29. IPCC. Summary for Policy Makers. Climate Change 2001, The Science of Climate Change, 2001.
30. Turner R, Boyer M. Mississippi River Diversions, Coastal Wetland Restoration/creation and an Economy of Scale. 1997.
31. IPCC 94. Climate Change: Radiative Forcing of Climate Change and an Evaluation of the IPCC, 1994.
32. IPCC 95. Climate Change: The Science of Climate Change 1995.
33. Burekett V. Kusler J. Climate Change: Potential Impacts and Interactions in Wetlands of the United States. 2000.
34. Wylynko D. Prairie Wetlands and Carbon Sequestration: Assessing Sinks under the Kyoto Protocol. Seehttp://iisd1.iisd.ca/wetlands/wrkshp_summ.pdf, 1999.
35. Wassmann RR. Latin H, Neue, Methane Emissions from Major Rice Ecosystems, 2001.
36. Gleason R, Euliss JR. Sedimentation of Prairie Wetlands, 1998.
37. Titus J. (ed.). Greenhouse Effect, Sea Level Rise and Coastal Wetlands, 1987.
38. Kimble JR, Mausbach M. Erosion Effects on Soil Organic Carbon Pools in Iowa, 2001.
39. Huntington T. Carbon Sequestration in an Aggrading Forest Ecosystem, 1995.
40. IPCC. Climate change impacts on forests". In: Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change, 1996b.
41. IPCC, 1996: Climate Change: The Science of Climate Change. Contribution of Working Group I, to the Second Assessment Report Intergovernmental Panel on Climate Change, 1995.
42. Weltzin JJ. Pastor C. Harth. Response of Bog and Fen Plant Communities to Warming and Water-table Manipulations. 2000.
43. Kusler J, Kentula M. (eds.). Wetland Creation and Restoration: The Status of the Science Island Press, Washington, D.C. 1990.
44. Callender E, Smith RA. Deposition of Organic Carbon in Upper Mississippi River Reservoirs, Transport of Carbon and Nutrients in Lakes and Estuaries Part 6 1993.
45. Birdsey R. Carbon Storage and Accumulation in United States Forest Ecosystems, 1992.
46. Adams J. Estimates of Total Carbon Storage in Various Important Reservoirs, 2000.
47. Houghton J. Summary for Policy Makers, Report of the Working Group, 2001.
48. Immirzi P. Maltby K. The Global Status of Peatlands and Their Role in the Carbon Cycle. Report No. 11, Wetland Ecosystems Research Group, 1992. University of Exeter, United Kingdom.
49. Dixon R, Krankina O. Can the Terrestrial Biosphere be managed to? Conserve and Sequester Carbon? Global Environmental Change 1995: 33:153-179.
50. Cao MK, Gregson, Marshall S. Global Methane Emission from Wetlands and its Sensitivity to Climate Change. Atmospheric Environment 1998: 32(19):3293-3299.
51. Gauci V, Dise N. Controls on Suppression of Methane Flux From a Peat Bog Subjected to Simulated Acid Rain Deposition. 1996.
52. Mathews E, Fung I. Methane Emission from Natural Wetlands, 1987.