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A review on climate change effects on vegetation – Past and future

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Abstract
There is significant current interest and research focus on the phenomenon of recent anthropogenic climate changes or global warming. Focus is on identifying the current impacts of climate change on vegetation and predicting these effects into the future. Changing climate variables relevant to the function and distribution of plants include increasing global temperatures, altered precipitation patterns and changes in season as well as the pattern of extreme weather such a cyclones, fires or storms. Evidences of these changes are inferred from changes in proxies, indicators that reflect climate such as vegetation, ice cores, dendrochronology, sea level change, glacial geology, and archaeological evidences. The main drivers of these changes have been temperature and carbondioxide as well as other greenhouse gases. These drivers increase at a much faster rate by anthropogenic activities than natural influences. Thus this review aims at analyzing at a large scale, the effects of these changes on different vegetation types and on biodiversity and the predictions of these effects on the future vegetation.

1. Introduction

Climate change refers to a change in the state of the climate that can be identified by changes in the mean and/or variability of its properties and that persists for extended periods, typically decades or longer [(1)]. Vegetation is a general term for plant life, it also refers to the ground cover provided by plants, without specific reference to particular taxa, life forms, structure, spatial extent or any other specific botanical or geographic characteristics, therefore an effect on a plant life, distribution or botanical characteristics consequentially affects the nature of the vegetation. Climate change may be due to natural causes and/or the result of human activities. According to IPCC, the extent of climate change effects on individual region will vary over time and with the ability of different societal and environmental systems to mitigate or adapt to change.

However, global average temperatures have risen by on average 0.74^0C over the past century (1906 – 2006) with the warming rate for the last 50years nearly twice that of the last 100 years [(1)]. In 2006, the Stern review calculated 977 – 99% change of a 2^0C rise before 2035 and at least a 50% chance of exceeding 5^0C during the following decades [(2)].

Increased CO_2 levels in the atmosphere as a result of climate change will alter global temperatures and rainfall amounts. These factors will influence how well plants grow and affect food production. So changes in temperature and precipitation patterns is a result of climate change are likely to be bad for large areas of the world but may increase crop production in other regions for the moment. However, one of the likely outcomes of climate change is also an increase in the severity of rainstorms and drought and both of these are likely to have large and devastating effects on agriculture. The negative effects of climate change are usually much larger than the positive ones. Research indicates that our climate will not necessarily change smoothly this time and that the intensity and forcings of climate on the environment and society could, at least on regional basis, be abrupt and non-linear with potentially devastating and unplanned–for consequences [3,4]. Effects that scientist had predicted in the past would result from global climate change are now occurring; loss of sea ice, accelerated sea level rise, droughts and more intense heat waves.

Scientists have high confidence that global temperature willl continue to rise for decades to come, largely due to greenhouse gases produced by human activities which is causing global warming [1].

1.1. Causes of Climate Change

Before the presentation of effects of climate change on vegetation, it is important to understand extensively the causes of climate change. On the broadest scale, the rate at which energy is received from the sun and the rate which it is lost to space determine the equilibrium temperature and climate of the earth. This energy is distributed around the globe by winds, ocean currents, and other mechanisms to affect the climate of different regions [5].

Factors that can shape climate are called climate forcing or “forcing mechanisms. Forcing mechanisms can be either “internal” or “external”. Internal forcing mechanisms are natural processes within the climate system itself (e.g, the thermohaline circulation). External forcing mechanisms can be either natural or anthropogenic (e.g, increased emissions of greenhouse gases). Whether the initial forcing mechanisms is internal or external the response of the climate system might be fast (e.g, a sudden cooling due to airborne volcanic ash reflecting sunlight), slow (e.g, thermal expansion of warming ocean water), or a combination (e.g, sudden loss of Albedo in the arctic as sea ice melts, followed by more gradual expansion of the water) [6]. Therefore, the climate system can respond abruptly but the full response to forcing mechanisms might not be fully developed for centuries or even longer.

1.1.1. Internal Forcing Mechanism

Scientists generally define the five component of earth’s climate to include atmosphere, cryosphere, hydrosphere, lithosphere and biosphere. Change in the components of earth’s climate system and the interactions are the causes of internal climate variable or internal forcing.

Ocean Variability

The ocean is a fundamental part of the climate system, some changes in it occurring at longer times than in the atmosphere, massing hundreds of times and having very high thermal inertial (such as the depths still lagging today in temperature adjustment from the little ice age) [7, 8].

Ocean currents move vast amounts of heat across the planet. Winds push horizontally against the sea surface and drive ocean current patterns. Deep ocean circulation between the oceans and atmosphere can also produce phenomena such as El Nino which occur every 2-6 years. Deep ocean circulation of cold water from poles toward the equator and movement of warm water from the equator back toward the poles, without this movement the poles would be colder and equation warmer. The oceans play an important role in determining the atmospheric concentration of CO_2. Changes in ocean circulation may affect the climate through the movement of CO_2 into or out of the atmosphere.

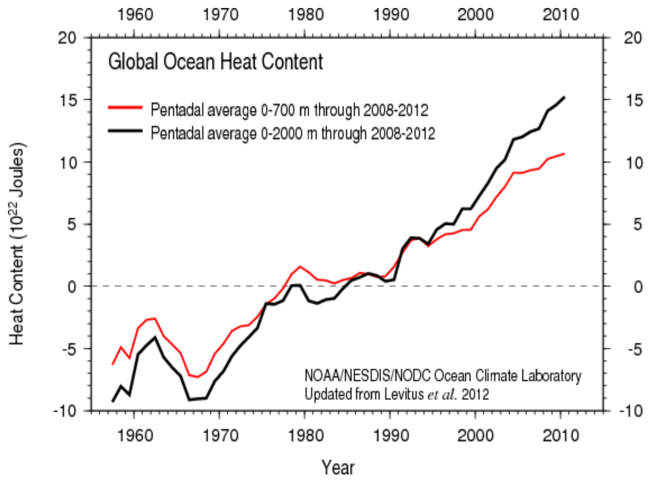

Figure 1. *Increase in ocean temperatures over the last decades*

Global ocean heat has increased since the last decade this is favours the flow of CO_2 out of the atmosphere thereby promoting climate change.

Life

Life affects climate through its role in the carbon and water cycles and such mechanisms as cloud formation, weathering, Albedo and evapotranspiration [9]. Examples include: glaciations 2.3 billion years ago triggered by the evolution of oxygenic photosynthesis [10], termination of the Paleocene – Eocene thermal maximum 55 million years ago by flourishing marine phytoplankton [11], glaciations 300 million years ago ushered by long-term burial of decomposition resistant detritus of vascular land plants (forming coal) [12], reversal of global warming 49 million years ago by 80,000 years of arctic Azolla bloom [13] and global cooling over the past 400 million years driven by the expansion of grass-grazer ecosystem [14].

1.1.2. External Forcing Mechanisms

Earth Orbital Changes

The earth makes one full orbit around the sun each year. It tilts an angle of 23.5^0 to the perpendicular plane of its orbital path [15]. More tilt leads to warmer summers and colder winters; less tilt means cooler summers and milder winters. Slow change in the earth’s orbital lead to small but climatically important changes in the strength of the season over tens of thousands of years, thereby producing ice ages [16].

Volcanic Eruptions

When a volcano erupts it throws out large volumes of sulphurdioxide (SO_2), water vapour, dust and ash into the atmosphere [17]. Large volumes of gases and ash can influence climatic pattern for years by increasing planetary reflectivity causing global warming and massive extinctions [18]. Tiny particles called aerosols and gases produced by volcanoes reflect solar energy back into space which has a cooling effect on the world (by partial bockage of solar radiation to the earth surface [19, 20].

Solar Variations

The sun is the source of energy for the earth's climate system, although the sun's energy output appears constant from an everyday point of view, small changes over an extended period of time can lead to climate changes. Some scientists suspect that a portion of the warming in the half of the 20th century was due to an increase in the output of solar energy [21]. Scientific studies demonstrate that solar variations have performed a role in past climate changes [22].

Plate Tectonics

Over the course of millions of years, the motion of tectonic plates reconfigures global land and ocean areas and generated topography; this can affect both global and local patterns of climate and atmospheric ocean circulation [23]. The position of the continents determines the geometry of the oceans and therefore influences patterns of oceans circulation. The location of the seas are important in controlling the transfer of heat and moisture across the globe, and therefore, in determining global climate. During the carboniferous period, about 300-360 million years ago, plate tectonics may have triggered large-scale storage of carbon and increased glaciations[24]. Geologic evidence points to a "meg a monsoonal" circulation pattern during the time of the supercontinent Pangaea, and climate modeling suggests that the existence of the supercontinent was conductive to the establishment of monsoons [25].

1.1.3. Human Causes of Climate Change

In the context of climate variation; anthropogenic factors are human activities which affects climate and is largely irreversible [26]. It has been demonstrated beyond reasonable doubt that the climate is changing due to man-made greenhouse gases, aerosol (small particles), and cloudiness. The largest known contribution comes from the burning of fossil fuels, which releases carbondioxide gas to the atmosphere and changes in land use including agriculture and deforestation. Greenhouse gases and aerosols affect climate by altering incoming solar radiation and out going infra red (thermal) radiation that are part of earth's energy balance. Changing the atmospheric abundance or properties of these gases and particles can lead to a warming or cooling of the climate system. Since the start of the industrial era, human activities affect climate by warming influence [6]. After 8,000 generations of *Homosapiens,* it is at least 90% certain that global warming is caused by human activities [1] which Joint attribution also demonstrated statistically [27].

The principal GHGs, which are essential to life by reducing the loss of heat to space, are water vapour (H_2O), carbondioxide (CO_2), methane (CH_4), nitrous oxide (NO_2) and ozone (O_3). Likewise, excess GHGs can raise the temperature of the planet. We are increasing the concentration of GHGs in the atmosphere, principally by fossil fuel combustion, forest burning and agriculture [28]. The global atmosphere Co_2 concentration ranged from 180-300 parts per million (ppm) over the past 400,000 years and varied roughly within a 270-290ppm over the past 1000 years [29]. The pre-industrial concentration of CO_2 in the atmosphere was 280ppm [30]. Global GHG emissions due to human activities have gown since pre-industrial times with an increase of 70% between 1970 and 2004 [1]. Using the IPPC's formula, they are 459ppm [31]. The lowest projected increase is for the concentration of over 520ppm by the end of this century [30].

1.1.4. Historical Evidence and Examples of Climate Change

Climate change in the recent past may be detected by corresponding changes in settlement and agricultural patterns. Archaeological evidence, oral history and historical documents can offer insights into past changes in the climate. Climate change effects have been linked to the collapse of various civilizations.

Glaciers

Glaciers are considered among the most sensitive indicators of climate change [32]. Their sizes determine by a mass balance between snow inputs and melt output. As temperature warm, glaciers retreat unless snow precipitation increase to make up for the additional melt; glacial grow and shrink due to natural variability and external forcing.

Arctic Sea Ice Loss

The decline in artic sea ice, both in extent and thickness, over the several decades is further evidence for rapid climate changes. Sea ice is frozen seawater that floats on the ocean surface. It covers millions of square miles in the regions, varying with the seasons. In the artic, some sea ice remains year after year whereas almost all southern ocean or Antarctic sea ice melts away and reforms annually. Satellite observations show that Arctic sea ice now declining at the rate 11.5% per decade, relative to the 1979 - 2000 average. A change in the type, distribution and coverage of vegetation may occur given a change in the climate.

Vegetation: A change in type, distribution and coverage of vegetation may occur given a change in the climate. Some changes in climate may result in increased precipitation and warmth, resulting in improved plant growth and subsequent sequestration of airborne CO_2. A gradual increase in warmth in a region will lead to earlier flowering and fruiting times, driving a change in the timing of life cycles of dependent organisms. Conversely, cold will cause plant biocycles to lag larger, faster or more radical changes, however, may result in vegetation stress, rapid plant loss and desertification in certain circumstances [33, 34]. An example of this occurred during the Carboniferous Rainforest Collapse (CRC), an extinction event

300 million years ago, At this time vast rainforest covered the equatorial region of Europe rainforests, abruptly fragmenting the habit into isolated animal species [34].

From 1982 to 1999, Satellite data available in recent decades indicates that global terrestrial net primary production increased by 6% with the largest portion of that increase in tropical ecosystems, then decreased by 1% from 2000 to 2009 [35, 36].

Pollen Analysis

Palynology is the study of contemporary fossil palynomorphs, including pollen. Palynology is used to infer the geographical distribution of plant species, which vary under different climate conditions. Different groups of plants have pollen with distinctive shapes and surface textures, and since the outer surface of pollen is composed of a very resilient material they resist decay. Changes in the type of pollen found in different layers of sediment in lakes, bogs, or river deltas indicate changes in plant communities, these changes are often a sign of a changing climate [37]. As an example, polynomial studies have been used to stack changing vegetation patterns throughout the quaternary glaciations and especially since the last glacial maximum [38].

Precipitation

Past precipitation can be estimated in the modern era the global network of precipitation gauges. Surface coverage over oceans and remote areas is relatively sparse, but reducing reliance on interpolation, satellite data has been available since the 1970s [39]. Quantification of climatological variation in precipitation in prior centuries and epochs is less complete but approximated using proxies such a mane sediments, ice core, care stalagmites, and tree ring [40]. Climatologically, temperatures substantially affect precipitation. In contrast, the world's climate was welter than today near the start of the warm Atlantic period of 8000 years ago [41]. Estimated global land precipitation increased by approximately 2% over the course of the 20th century, though the calculated trend varies if different time endpoints are chosen [39].

Dendroclimatology

Dendroclimatology is the analysis of tree growth patterns to determine past climate variations. Wide and thick rings indicate a fertile, well-watered growing period, whilst thin narrow rings indicate a time of lower rainfall and less than-deal growing conditions.

Ice Cores

Analysis office in a core drilled from an ice sheet such as the Antarctic ice sheet can be used to show a link between temperature and global sea level variations. The air trapped in bubbles in the ice can also reveal the CO_2 variations of atmosphere from the distant past before modern environmental influences. The study of these ice cores has been a significant indicator of the changes in CO_2 over many millennia, and continues to provide information about the differences between ancient and modern atmospheric conditions.

Animals

Different species of beetles tend to be found under different climatic conditions. Given the extensive lineage of beetles whose genetic makeup has not been altered significantly over the millennia, knowledge of the present climatic range of the different species and the age of the sediments in which remains are found, past climatic conditions may be inferred [42]. Similarly, the historical abundance of various fish species has been found to have a substantial relationship with observed climate conditions. Changes in the primary productivity autotrophs in the oceans can affect marine food webs [43]

Sea Level Change

Global sea level change for much of the last century has generally estimated using tide gauge measurements collated over long period of time to give a long-term average. More recently, altimeter measurements in combination with accurately determine satellite orbits have provided an improved measurement of global sea level change [44]. To measure sea levels prior to instrumental measurements, scientists have dated coral reefs that grow near the surface of the ocean, costal sediments, marine terraces, ooids in limestones, and near shore archaeological remains. The predominant dating methods used are Uranium series and radio-carbon, with cosmogenic radio nuclides being sometimes used to date terraces that have experienced relative sea level fall. In early Pliocene, global temperatures were 1-2^{0}C warmer than present temperature, yet sea level was 15-25 meters higher than today [45].

1.2.1. Effects of Climate on Plant Biodiversity

Environmental conditions play role in defining the function and distribution of plants, in combination with other factors. Changes in long term environmental conditions that can be collectively coined climate change are known to have had enormous impacts on plant diversity patterns in the past and are seen as having significant current impacts. It is predicted that climate change will remain one of the major drivers of biodiversity patterns in the future [46].

Palaeo Context

The earth had experienced a constantly changing climate in the time since plants first evolved. In comparison to the present day, this history has seen earth as cooler, warmer, drier and wetter, CO_2 (carbondioxide) concentrations have been both higher and lower [47]. These changes have been reflected by constantly shifting vegetation, for example forest communities dominating most areas in interglacial periods and herbaceous communities during glacial periods [48]. It has been shown that past climatic change has been a major driver of the processes of speciation and extinction. The best known example of this is the carboniferous rainforest collapse which occurred 35 million years ago, this event decimated amphibian population and spurred on the evolution of reptiles [34].

Effects of CO_2

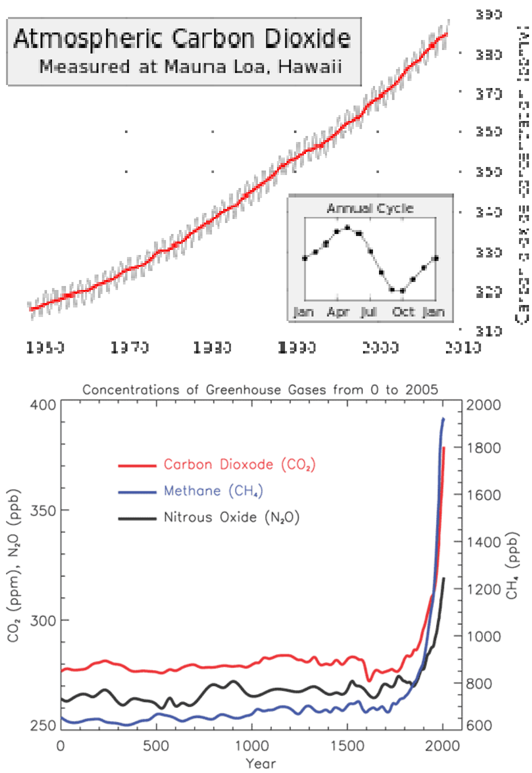

Figure 2. *Increase in atmospheric carbondioxide; an important driver of climate change Of all the greenhouse gases, CO_2 has been the most on increase*

Increase in atmospheric CO_2 concentration affect how plant photosynthesize resulting in increase in plant water use in efficiently enhanced photosynthetic capacity and increased growth [49]. Increased CO_2 has been implicated in vegetation thickening which affects plant community structure and function [50]. Depending on environment, there are differential responses to elevated atmospheric CO_2 between major functional types of plant such as C_3 and C_4 plants, or more or less woody species; which has the potential among other things to alter competition between these groups [51]. Increased CO_2 can also lead to increased carbon: nitrogen ratios in the leaves of plants or in other aspects of leaf chemistry, possibly changing herbivore nutrition [52].

Effects of Temperature

Increases in temperature raise the rate of many physiological processes such as photosynthesis in plants, to an upper limit. Extreme temperatures can be harmful when beyond the physiological limits of plant. The globally averaged combined land and ocean temperature data as calculated by a linear trend show a warming of 0.85 (0.65 to 1.06)°C over the period 1880 - 2012, when multiplied independently produced datasets about 0.89 (0.69 to 1.08)°c over the period 1901- 2012, and about 0.72 (0.49 to 0.89)°c over the period 1951 -2012 when basedon three independently-produced data sets [53].

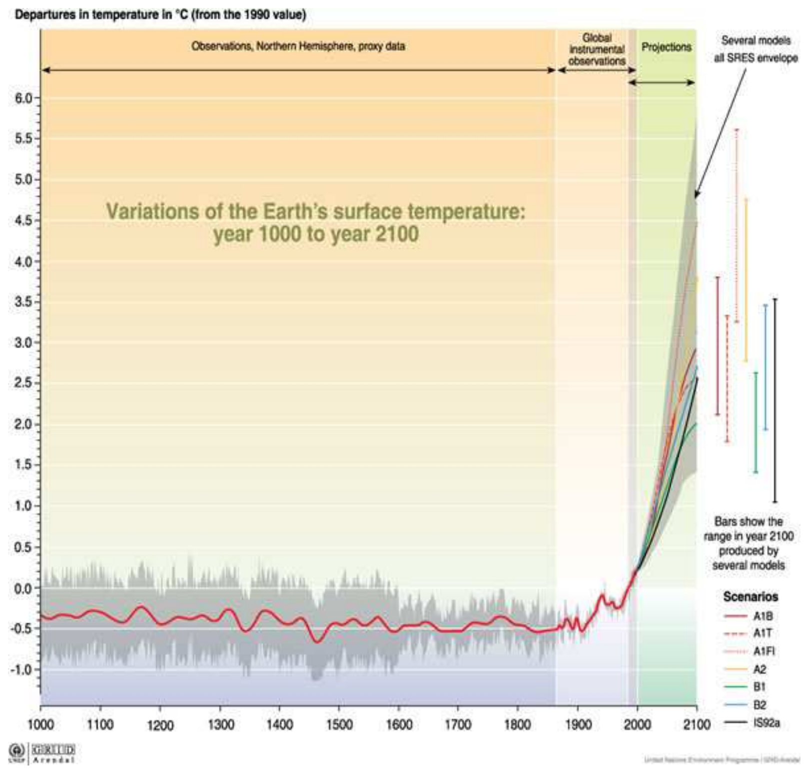

Figure 3. *Drastic increase in temperature since 1900 and predicted boiling of the earth by 2100*

The earth has observed variation in surface temperature, however abnormal increased has been observed since1900 and predictions reveal a boiling by 2100.

Effects of Water

As water supply is critical for growth it plays a key role in determining the distribution of plants. Changes in precipitation are predicted to be less consistent than for temperature and more variable between regions, with predictions for some areas to become much wetter, and some much drier.

General Effects

Environmental variables will not act in isolation, but also in combination with another, and with other pressures such as habit degradation and loss or the introduction of exotic species. It suggested that these other drivers of biodiversity change will act in synergy with climate change to increase the pressure on species to survive [54].

1.2.2. Direct Impacts of Climate Change

Change in Distributions

If climate factor such as temperature and precipitation change in a region beyond the tolerance of a species phenotypic plasticity the distribution changes of the species may be inevitable [55]. There is already strong evidence that plant species are shifting their ranges in altitude and latitude as a response to changing regional climates [56].

Figure 4. *Loss of vegetation composition*

Prolonged climate channge may result in change in vegetation type due to loss of vegetation composition

When compared to the reported past migration rates of plant species, the rapid pace of current changes has the potential to not only alter species distributions, but also render many species as unable to follow the climate to which they are adapted. The environmental conditions required by some species, such as those in alpine regions may disappear altogether. The result of these changes is likely to be rapid increase in extinction risk [57]. Adaptation to new condition may also be of importance in the response of plants [58]. Predicting the extinction risk of plant species is not easy however, estimation from particular period of rapid climatic change in the past have shown relatively little species extinction in some regions, knowledge of how species may adapt or persist in the face of rapid change is still relatively limited[59]. Changes in the suitability of a habitat for a species drive distribution changes by not only changing the area that a species can physiologically tolerate, but how effectively it can compete with other plant within this area, changes in community composition and therefore also an expected product of climate change.

Changes in Lifecycles (Phenology)

The timing of phenological events such as flowering is often related to environmental variables such as temperature. Changing environments are therefore expected to lead to changes in life cycle events and these have been recorded for many species of plants [56]. These changes have the potential to lead to the asynchrony between species, or to change competition between plants. Flowering times in British plants for example have changed, leading to annual plants flowering earlier than perennials, and insect pollinated plants flowering earlier than wind pollinated plants; with potential ecological consequences [60].

1.2.3. Indirect Impacts of Climate Change

All species are likely to be not only directly impacted by the changes in environmental condition discussed above also indirectly through their interactions with other species. While direct impacts may be easier to predict and conceptualize, it is likely that indirect impacts are being equally important in determining the response of plants to climate change [61]. A species whose distribution changes as a direct result of climate change may “invade” the range of another species for example, introducing a new competitive relationship. The range of a symbiotic fungi associated with plant root may directly change as a result of altered climate, resulting in a change in the plant distribution. A new grass may spread into a region, altering the fire regime and greatly changing the species composition.

A pathogen or parasite may change interactions with a plant, such as a pathogenic fungus becoming more common in an area where rainfall increases. Increased temperature allows herbivores to expand further into Alpine regions, significantly impacting the composition of Alpine. There are innumerable examples of how climate change could indirectly affect plant species, most of which will be extremely difficult to predict.

1.3.1. Adaptation of Plants to Climate Change

Plants can/do adapt to changes in their environment, with a classic example coming from the rapid evolution of heavy metal tolerance in plants on mine site tailings [62] and more recent examples coming from herbicides resistance in a populations of weeds [63]. However, plant adaptive responses to climate change are likely to be slower than plant responses to single pollutants, since adaptation to pollutants normally only involves one or two traits whereas adaptation to climate change is likely to involve many traits.

The fossil record indicates that in the past, species have been able to adapt or move in response to climate change, but this has been dependent on a natural landscape. Further, from the perspective of the world's plant species, current changes in climate are occurring in the context of many other stresses such as pollution, land use change and population increase. Current observations revealed a climate that is more sensitive than anticipated, with changes occurring sooner and more intensely than predicted [95].

Climate is the primary control of species distributions and ecosystem processes both now [64, 65] and throughout history [66]. What differs now from history is the rate of change, the increasing frequency of extreme events and the fact that many of the changes in the environment are human- caused [67]. According to Hawkins *et al* 2008, though uncertainties remain about the extent of changes, the likely effects are;

1. Higher average land and sea temperatures.
2. More rainfall globally from increase evaporation.
3. More variability in rainfall and temperature with more frequent and more severe floods and droughts.
4. Rising sea levels from warming water and from melting ice masses.
5. Increased frequency and severity of extreme weather events such as hurricanes.
6. Shifting ranges of vegetation species with cascade ecosystem effects.
7. Expanding range of pathogens, such as mosquitoes.

The extent of future climate change depends on what we do now. The smaller the climatic shift the more species are likely to be able to persist, and the greater the genetic diversity preserved. Biodiversity equals ability to adapt. Healthy ecosystems are more likely to be able to adapt to future climate change, and continue to provide us with ecosystem services vital to our own existence.

1.3.2. The Physiological Responses of Vegetation to Climate Change

The diversity and distribution of the world's terrestrial vegetation is the product of' a complex suite of interactions between individual plants and a multitude of climatic and environmental variables. Plants are major regulators of the global climate, and their collective responses to increased atmospheric CO_2 concentrations have clearly played an important role in mitigating climate change. The uptake of CO_2 by plants during photosynthesis is the major pathway by which carbon is stored [29]

In looking to the future, it is increasingly critical to understand how plants respond on a basic level to the changes imposed upon them by continued increases in atmospheric CO_2, as well as the cascade of climatic and environmental changes triggered by this increase. While plant response to changes in single variables, such as CO_2 or temperature, are increasingly well-understood. Recent discoveries illustrate the many ways in which the world's plant can easily loose their ability to act as a global carbon sink, becoming instead yet another carbon source [28]

Net Primary Production (NPP) and Net Ecosystem Production (NEP)

Primary production occurs when chemical or solar energy is transformed to useable biomass. Most primary production on the planet occurs via photosynthesis, a process that allows plants to convert solar energy, water and CO_2 into useable carbohydrates. Plants as primary producers are thus instrumental in remaining CO_2 from the atmosphere, and turning it into a product that stores the carbon, ultimately playing a key role in limiting CO_2 as a greenhouse gas in the atmosphere. NPP is the net result of CO_2 fixation by photosynthesis and CO_2 loss by plants respiration. The product of NPP is organic matters which accumulates first as living matter then decomposes, thus losing carbon by respiration. Rates of primary production and respiration are affected by temperature (normally increasing with warming). NEP is the difference between gross primary product and total ecosystem respiration (including plants as well as other organisms in the ecosystem) and represents the total amount of organic carbon available in an ecosystem for storage or loss [68]. NEP and organic carbon accumulation rates are not always equivalent.

Climate change may also affect NEP and NPP by altering an ecosystem's moisture regime, nitrogen availability and growing season length, among other things. From this multi-step, indirect effects may cascade and affect other ecosystem processes, for example litter quantity for many ecosystems, the indirect effects of a temperature increase on carbon balance are likely to be more important than the direct effects [69].

Plant Response to Rising CO_2

Land plants utilize one of three modes of photosynthesis; C_3, C_4, (so called balance because the CO_2 is initially incorporated into either 3-carbon of 4-carbon compounds) and CAM (Crassulacean acid metabolism, named after the plant family in which it was first found).

1. Increase Growth: Photosynthesis by terrestrial plants accounts for about half of the carbon that annually cycles between earth and the atmosphere. Most C_3 land plants respond to elevated CO_2 by increased net photosynthesis. It is generally accepted that this leads to an increase in growth and yield, conditions permitting. The ability of plants to produce additional biomass is one of the potential reasons that terrestrial plants have become increasingly greater carbon sinks over the past 50 years, keeping CO_2 build up in the atmosphere at 40-50% of what it would otherwise be due to our emissions [70]. C_4 plants respond similarly to C_3 plants (i.e most plants) but to a lesser degree and CAM plants hardly at all, because these photosynthetic pathways already function so as to minimize photorespiration.
2. Eventual Acclimatization: Some studies indicate climate-driven increases in global net primary

terrestrial production [35] after eventual acclimatization to higher CO_2. However, short term photosynthetic responses are decreased (initial increases in growth and yield stop). Infact, long term exposure to elevated CO_2 leads to the accumulation of carbohydrates in the photosynthetic tissues of the plant and this in turn leads to a reduction in photosynthetic rates [71]. Further, although CO_2 initially enhances plant growth rates, in some regions the larger effects of increased drought (also associated with climate change) will lead to lower growth overall.

3. Lower Nutritional Value: As well as this down-regulation of photosynthetic capacity, plants that do respond to elevated CO_2 produce tissue with lower nutrient concentrations (reduced leaf nitrogen (N) content)[72]. This has clear implications for herbivores as well as for decomposers [73] and for humans, also considering the implications of nutrient content decrease of staple crops such as potatoes [72]. As food quality decreases, more must be grown and consumed to obtain the same benefit.
4. Increased Nitrogen Needed: Although increased CO_2 makes C_3 plants grow larger initially, plants growing faster and larger need more nutrients such as nitrogen with cascade effects on soil quality [74].
5. Reduced Stomatal Density: Stomata are pores on the surface of leaves that open and close to allow gas exchange between the plant and the atmosphere. In a single leaf, the stomatal density of some species decreases with increased CO2, since either the u opportunity for water conservation is of more importance than grapping benefit of rising CO_2 or less stomata are needed to receive equivalent amounts of CO_2 [75].
6. Reduced Transpiration: Plants in increased CO_2 environments frequently either open their stomata less widely or keep their stomata completely closed more often, therefore reducing transpiration [76]. Additionally, transpiration is largely responsible for the ability of plants to cool their local climate; the loss of this cooling effect could be significant. Further reduced transpiration may allow plants to extract less water from the soil, leaving more water at the land surface. [77].
7. Species Specific Responses: Whilst many species of plants acclimatize to elevated CO_2 relatively quickly; many others do not. Plants with growth strategies or photosynthetic pathways that allow them to take advantage of changing condition in any given habitat will gain a relative advantage over those that do not. Species with rapid growth rates may be responsive than slower grounding species. Within these responses, there will also be a genetic performances and varying genetic adaptability of species/populations [78].

Plant Responses to Temperature Changes

The direct effect of warming in plants and ecosystems will be complex because temperature impacts virtually all chemical and biological processes. However, the effect of temperature changes is likely to be larger and more important than any other factor [79]. In turn, changes in vegetation composition may have significant effects on the local heat balance [80].

Additionally, plant tissue chemistry modifications caused by elevated CO_2 may affect responses to warming [69] for example, by no energy for evaporation (reduced transpiration) the temperature of both the plant (leaf surface) and its surroundings will increase. In this way, the air conditioning effect of plants is reduced, particularly during periods of water stress.

1. Too Much Heat: The drought in Europe in 2003 combination unusually high temperatures with water stress and reduced primary productivity by 30% [94]. If temperature increases too much, faster respiration may tip the balance towards plants becoming a CO_2 source. Temperature rise may also affect habitat composition, since generally, C_3 plants are more sensitive to heat stress than C_4 and CAM plants [81].
2. Extended Growing Season: There are widespread examples of extended growing seasons due to temperature rise and concomitant changes in key biological process including earlier budburst, delayed autumn leaf fall, and extended flowering. The early onset of spring across the northern hemisphere has been particularly well documented [82, 83] with an observed advance in European spring/summer of 2.5days per decade and a two day delay in autumn [84]
3. Dormancy: Dormancy is a period of limited to no growth which enables plants to survive temporary climatic extremes, such as subzero winter conditions or prolonged drought. It has evolved to ensure that plants have no soft growing tissue that could be damaged by prevailing seasonal weather. Some species use temperature. Cues as a sign that it is safe to break dormancy in order to maximize growth during favourable climatic conditions where temperature changes, ability of plant species to successfully predict appropriate times for growth is altered, development is impaired, resulting in the delay, abnormality or failure of flowers and fruits.
4. Unpredictable Weather: For many species, certainly in short term, it is not small differences in temperature that will affect them most, but rather the likelihood of sudden weather events, for example sudden frosts after periods of warmth [79]. It is not just the magnitude of the change but the unpredictability of the change. Early onset of growth in response to mild weather combined with unexpected frosts is likely to cause significant damage to plants.
5. Snow: Snow insulates and protects plant from the harshest conditions of winter, such as freezing temperatures and desiccating winds Shorter winters and less snow will potentially greatly increase the severity of temperatures experienced by some plants,

particularly alpine species. This relatively overlooked aspect of global climate change is likely to be a critical factor affecting plant survival in some areas.

Other aspects of plant responses according to Hawkins *et al* 2008 includes

- Responses to available water

a. Water vapour

b. Water stress

c. Water logging

With case studies on the growth of beech (*Fergus sylvatica*) trees.

Plant responses to tropospheric ozone (0_3).

- The nitrogen cycle in a changing climate

a. Carbon-nitrogen-climate interactions

b. Nitrogen and plants

c. Nitrogen and soils

d. Added nitrogen

e. Decomposition and nitrogen

- Responses to light levels.

1.4.1. An Interaction of Climate

Terrestrial plants have the ability to act as carbon sinks with increasing atmospheric CO_2 concentration environmental factors will determine when and where terrestrial plants are able to store excess carbon and will therefore play a key role in shaping the current and future climate of the globe. Individual species will differently, leading to changes in species composition and ecosystem structure. The smaller the temperature rise the more likely the plant complex will be able to adapt and continue to support all other life.

Observing and predicting plant responses to climate change

1. Observations such as earlier budburst and longer growing seasons confirm that the behaviour of plant species is changing in response to climate change.
2. Observations also show changes in species distribution over the past 30 years.
3. Predictions of future plant species ranges are critical for conservation planning, but can only be obtained through modeling.
4. Models must be treated with caution as they do not take into local situations such as plant-to-plant interactions, dispersal ability or plant adaptability to changing environments.
5. Lack of data on existing plant distribution is a further limitation to modeling approaches.
6. Experimental approaches which assess the climate tolerances of species can help to overcome some of the limitations of modeling.

1.4.2. Past Climates

Studies of past climates can elucidate how quickly and in what way certain vegetation types may respond to climate change. In Columbia in the 1950s for example, pollen analysis was undertaken on a sediment core from the Andres, more recent studies have contributed to this analysis to create a detailed fossil pollen history of the past 1.4 million years for the high plain of Bogota. The palaeobotanical record (from forests to shrubby subparamo to grassy paramo according to cold events) as well as intricate movements to individual taxa, such as Alnus and Quercus species. The strength of the pollen record of these species indicates temperatures and likely local flora [(85)].

Though the evidence for global carbon cycle-climate interactions on the times scale pertinent to current climate change (i.e decades) is scarce as compared to fossil, tree ring and ice core data, it is certain that climate change over the past 30 years has pronounced shifts in the distributions and abundance of pierces [(57, 27, 86)].

1.4.3. Plant Community Interactions

It is clear that different plant species will respond differently to climate change. Some species will stay in place but adapt to new climatic conditions through selection or plasticity. Other species will move to higher latitudes or altitudes. Some species may become extinct. Because of this, plant community composition will be reorganized, new communities will emerge and others will be lost. One of the biggest concerns of this community resifting is the disruption of food webs and coevolved mutualisms, such as the relationship between a plant and its pollinator or seed disperser. If species that rely on each other no longer co-occur in the same time or space, both may be driven to extinction, diseases pests, and invasive may spread into new range putting more pressure on fragile communities maintaining biodiverse communities will become an even greater conservation priority [(87)].

1.4.4. Past and Future Vegetation Shifts

In the past there have been major changes in the distribution of plant species brought about climatic change in turn; past climatic conditions have had a major influence on the current distribution of vegetation. Cooling climates towards the end of the tertiary (Approximately 65 million to 1.8 million years age) for example, resulted in large assemble of plant species from warm temperate and subtropical areas of warm wet conditions. These areas of plant refugee are in East Asia, South-eastern, North America, Western North America, Western North America and Southwest Eurasia (the Caucasus region) and are known as tertiary relict floras. Tertiary relict floras are great biogeographically interest because they show disjunct distribution of genera that were able to migrate along former land bridges between continents. They are also centers of biodiversity with a disproportionate number of globally threatened species. [(27, 86)].

Under changed climate, it is likely that new plant assemblage will be formed (community scale) and carbon as well as water cycling may change (ecosystem scale) resulting in altered functions and survives [(88)]. Infact, climate change will alter plant distribution, will stability, and will therefore influence service required life [(89)].

Further, in some areas, the relationship between climate change and vegetation is not reversible; this suggests that once an ecological threshold has been crossed, a return to similar climatic conditions does not guarantee a similar reversal in vegetation [90].

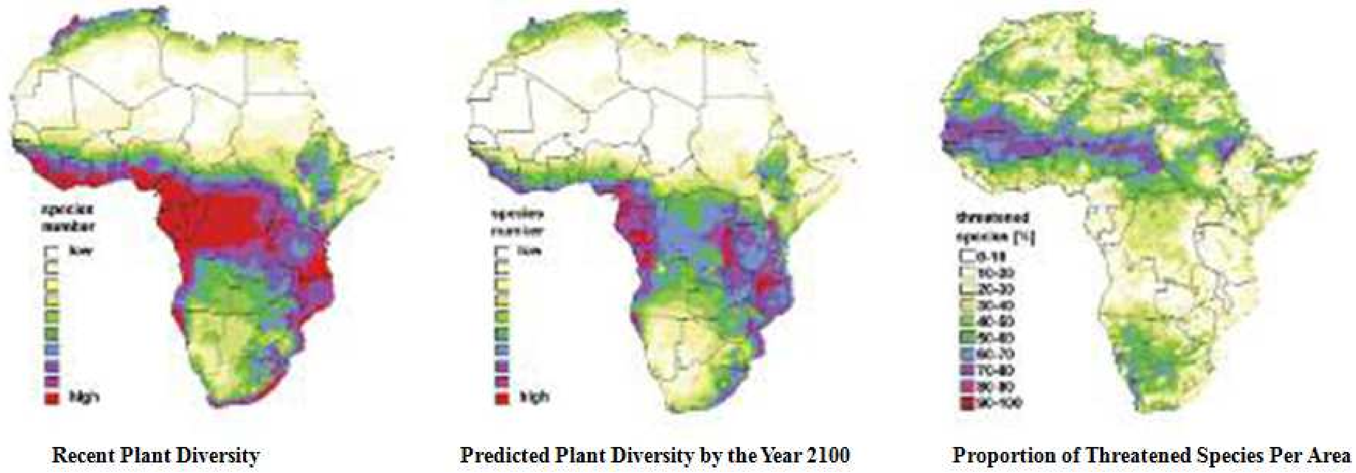

Figure 5. *Climate change: predicted decrease in plant species diversity by the year 2100*

•The geographic ranges of 90% of all species may decrease in average to about 50% of their recent range;

•Some areas may lose up to 80% of all species, in particular in the Sahel region;

•Up to 25% of all species may go extinct by the effects of climate change [91].

1.5.1. Ecosystems at Risk

An ecosystem is an array of living things and the physical and chemical environment in which they interact. Healthy ecosystems provide the conditions that sustain human life through the provision of a diverse range of ecosystem services. Plant diversity underpins terrestrial ecosystem and they are often described according to the major vegetation type they consist of. Many ecosystems will be highly vulnerable to projected rates and magnitudes of climate change and the service lost through the disappearance or fragmentation of ecosystems will be costly or impossible to replace. [96]

Forest ecosystems are particularly important, containing as much as two-thirds of all known terrestrial species and storing about 80% of above-ground and 40% of below-ground carbon. Ecosystems responses to climate changes will be complex and varied. Climatic changes will essentially affect all ecosystem processes but at different rates, magnitudes and directions. Responses will vary from the very short term responses to leaf-level photosynthesis to long-term changes in storage and turnover of soil carbon and nitrogen stocks [92].

1.5.2. Plant Species at Risk by Climate Change

Climate change results have been loss of critical habitat of species leading to extinction risks. The IUCN red list of threatened species has revealed over 8786 taxas some of which include;

Extinct Species (EX)

1. *Trapa natans* L. (Water caltrop)
2. *Aldrovanda vesiculosa* L.
3. *Rubus arcticus* L.
4. *Veratrum lobelianum* Bernh.
5. *Pedicularis kauffmannii* Pinzger
6. *Groenlandia densa* (L.) Fourr.
7. *Hypericum humifusum* L. (Trailing St.John's-wort)
8. *Caldesia parnassifolia* (L.) Parl.
9. *Gladiolus palustris* Gaudin (Marsh Gladiolus)
10. *Aphanes arvensis* L. (Parsley Piert)
11. *Hydrocotyle vulgaris* L. (Marsh Pennywort)
12. *Pycreus flavescens* (L.) P. Beauv. ex Rchb.
13. *Carex rhizina* Blytt ex Lindblom

Endangered Species (EN)

1. *Epipogium aphyllum Sw.*
2. *Sea aster (Aster tripolium* L.*)*
3. *Teucrium scordium* L.
4. *Dwarf Birch (Betula nana* L.*)*
5. *Isopyrum thalictroides L.*
6. *Bromopsis erecta* (Huds.) Fourr.
7. *Erica tetralix* L.
8. *Cephalanthera longifolia* (L.) Fritsch
9. Red Helleborine *(Cephalanthera rubra* (L.)Rich.)
10. *Hedera helix L.*
11. *Western marsh orchid (Dactylorhiza majalis (Rchb.) P. F. Hunt et Summerh.)*
12. *Dactylorhiza cruenta (O. F. Müll.) Soó*
13. *Orchis ustulata L.*
14. *Marsh Gentian (Gentiana pneumonanthe L.)*
15. *Gentianella uliginosa (Willd.) Börner*
16. *Pedicularis sceptrum-carolinum L.*
17. *Pedicularis sylvatica L.*
18. *Deptford Pink (Dianthus armeria L.)*
19. *Large Pink (Dianthus superbus L.)*
20. *Creeping Willow (Salix repens L.)*
21. *Conifer Bedstraw (Galium triflorum Michx.)*
22. *Lobelia dortmanna L.*
23. *Musk Orchid (Herminium monorchis (L.)*
24. *Melittis melissophyllum L.*
25. *Hordelymus europaeus (L.) Harz*

26. *Fen violet (Viola persicifolia Schreb.)*
27. *Fly Orchid (Ophrys insectifera L.)*
28. *Sea-milkwort (Glaux maritima L.)*
29. *Nymphoides peltata (S. G. Gmel.) Kuntze*
30. *Gymnadenia odoratissima (L.) Rich.*
31. *Neottianthe cuculata (L.) Schltr.*
32. *Potamogeton trichoides Cham. et Schltdl.*
33. *Slender Naiad (Najas flexilis (Willd.) Rostk. et W. L. E. Schmidt)*
34. *Niajas minor All.*
35. *Myriophyllum alterniflorum DC.*
36. *Tofieldia calyculata (*L.*) Wahlenb.*
37. *Gnaphalium luteoalbum* L.
38. *Hedge hyssop (Gratiola officinalis* L.*)*
39. *Succisella inflexa (Kluk) Beck*
40. *Love-nest sundew (Drosera intermedia Hayne)*
41. *Centaurium littorale (Turner ex Sm.) Gillmour*
42. *Carex davalliana Sm.*
43. *Carex magellanica Lam.*
44. *Schoenus ferrugineus* L.
45. *Saltmarsh Rush (Juncus gerardii Loisel.)*
46. *Moor Rush (Juncus stygius* L.*)*
47. *Sea holly (Eryngium maritimum L.)*
48. *Dracocephalum ruyschiana L.*

Vulnerable (VU)

1. Arnica montana L.
2. Seseli annuum L.
3. Centaurea phrygia L.
4. Betula humilis Schrank
5. Allium vineale L.
6. Bromopsis benekenii (Lange) Holub
7. Salsola kali L.
8. Neottia cordata (L.) R. Br.
9. Hydrilla verticillata (L. f.) Royle
10. Malaxis monophyllos (L.) Sw.
11. Dactylorhiza maculata (L.) Soó
12. Orchis morio L.
13. Orchis militaris L.
14. Orchis mascula (L.) L.
15. Gentiana cruciata L.
16. Gentianella amarella (L.) Börner
17. Corallorrhiza trifida Chātel.
18. Prunella grandiflora (L.) Scholler
19. Scutellaria hastifolia L.
20. Gladiolus imbricatus L.
21. Salix lapponum L.
22. Campanula bononiensis L.
23. Cypripedium calceolus L.
24. Trichophorum cespitosum (L.) C. Hartm.
25. Alyssum gmelinii Jord.
26. Hammarbya paludosa (L.) Kuntze
27. Thesium ebracteatum Hayne
28. Sesleria caerulea (L.) Ard.
29. Glyceria lithuanica (Gorski) Gorski
30. Pulicaria vulgaris Gaertn.
31. Silene chlorantha (Willd.) Ehrh.
32. Triglochin maritimum L.
33. Polemonium caeruleum L.
34. Coeloglossum viride (L.) Hartm.
35. Gymnadenia conopsea (L.) R. Br.
36. Najas marina L.
37. Liparis loeselii (L.) Rich.
38. Primula farinosa L.
39. Cladium mariscus (L.) Pohl
40. Agrostemma githago L.
41. Corydalis cava (L.) Schweigg. et Körte
42. Epipactis atrorubens (Hoffm.) Besser
43. Prunus spinosa L.
44. Arenaria saxatilis L.
45. Eriophorum gracile W. D. J. Koch ex Roth
46. Pinguicula vulgaris L.
47. Saxifraga hirculus L.
48. Cirsium heterophyllum (L.) Hill
49. Ajuga pyramidalis L.
50. Ranunculus reptans L.
51. Carex tomentosa L.
52. Iris sibirica L.
53. Trisetum sibiricum Rupr.

Rare

1. Astrantia major L.
2. Quercus petraea L. ex Liebl.
3. Laserpitium prutenicum L.
4. Allium angulosum L.
5. Allium scorodoprasum L.
6. Bromopsis ramosa (Huds.) Holub
7. Agrimonia procera Wallr.
8. Trifolium rubens L.
9. Trifolium lupinaster L.
10. Alisma lanceolatum With.
11. Alisma gramineum Lej.
12. Orobanche reticulata Wallr.
13. Festuca altissima All.
14. Dactylorhiza ochroleuca (Wüstnei ex Boll) Holub
15. Cnidium dubium (Schkuhr) Thell.
16. Chaerophyllum hirsutum L.
17. Dianthus borbasii Vandas
18. Hypericum montanum L.
19. Hypericum hirsutum L.
20. Salix myrtilloides L.
21. Cardamine flexuosa With.
22. Cardamine bulbifera (L.) Crantz
23. Campanula cervicaria L.
24. Koeleria delavignei Czern. ex Domin
25. Lithospermum officinale L.
26. Cruciata laevipes Opiz
27. Cruciata glabra (L.) Ehrend.
28. Pilosella echioides (Lumn.) F. W. Schultz et Sch. Bip.
29. Calamagrostis pseudophragmites (Haller f.) Koeller
30. Galium rubioides L.
31. Bolboschoenus maritimus (L.) Palla
32. Nuphar pumilum (Timm) DC.
33. Conioselinum tataricum Hoffm.

34. Isolepis setacea (L.) R. Br.
35. Scolochloa festucacea (Willd.) Link
36. Ceratophyllum submersum L.
37. Stachys recta L.
38. Swertia perennis L.
39. Lathyrus laevigatus (Waldst. et Kit.) Gren.
40. Lathyrus pisiformis L.
41. Pulmonaria angustifolia L.
42. Potamogeton ×meinshauzenii Juz.
43. Potamogeton acutifolius Link
44. Helictotrichon pratense (L.) Besser
45. Callitriche hermaphroditica L.
46. Tragopogon gorskianus Rchb. f.
47. Nasturtium officinale W. T. Aiton
48. Corydalis intermedia (L.) Mérat
49. Tanacetum corymbosum (L.) Sch. Bip.
50. Aira praecox L.
51. Geranium lucidum L.
52. Myrica gale L.
53. Salvia pratensis L.
54. Sherardia arvensis L.
55. Zannichellia palustris L.
56. Colchicum autumnale L.
57. Veronica polita Fr.
58. Veronica hederifolia L.
59. Vicia dumetorum L.
60. Vicia lathyroides L.
61. Vicia pisiformis L.
62. Carex heleonastes Ehrh.
63. Carex buxbaumii Wahlenb.
64. Carex distans L.
65. Carex pseudobrizoides Clavaud
66. Juncus capitatus Weigel
67. Gagea pratensis (Pers.) Dumort.
68. Radiola linoides Roth
69. Scabiosa columbaria L.

Indeterminate

1. Beckmannia eruciformis (L.) Host
2. Festuca psammophila (Hack. ex Čelak.) Fritsch
3. Common spotted orchid (Dactylorhiza fuchsii (Druce) Soó)
4. Dactylorhiza longifolia (Neuman) Aver.
5. Dactylorhiza incarnata (L.) Soó
6. Dactylorhiza russowii (Klinge) Holub
7. Dactylorhiza traunsteineri (Saut.) Soó
8. Cerastium sylvaticum Waldst. et Kit.
9. Cerastium brachypetalum N. H. F. Desp. ex Pers.
10. Taraxacum balticum Dahlst.
11. Taraxacum lissocarpum (Dahlst.) Dahlst.
12. Taraxacum suecicum G. E. Haglund
13. Astragalus cicer L.
14. Montia fontana L.
15. Mentha longifolia (L.) Huds.
16. Glyceria nemoralis (R. Uechtr.) R. Uechtr. et Körn.
17. Silene lithuanica Zapał.
18. Polycnemum arvense L.
19. Viola elatior Fr.
20. Viola uliginosa Besser
21. Alopecurus arundinaceus Poir.
22. Polygala wolfgangiana Besser ex Ledeb.
23. Ornithopus perpusillus L.
24. Epipactis purpurata Sm.
25. Dactylis polygama Horv.
26. Elatine hydropiper L.
27. Nymphaea alba L.
28. Carex muricata L.
29. Carex ligerica J. Gay
30. Androsace filiformis Retz.
31. Senecio congestus (R. Br.) DC.

1.5.3. Managing the Impacts of Climate Change on Vegetation

It is clear that many species of wild plants are likely to become extinct within the next century, and at least for some communities and ecosystems, climate change is already imposing huge costs. Uncertainly about how climate change will unfold or what the respondent species and habitats will be, must not prevent us from the taking urgent action now concerning vegetations to help in the maintenance of carbonsinks and will ensure options for the global strategy for plant conservation [93]. It also provides a useful framework for amending or developing additional plant conservation targets post-2010. The richest post vegetation in future depends on how we act and what we conserve today.

2. Conclusions

It is clear that climate change is happening now the direct effects of anthropogenic climate change been predicted. Future climate will depend on the actions we take now. There is much evidence that all stabilization levels assessed can be achieved by deployment of a fort folio of technologies that are either currently available or expected to be commercialized in coming decades. In order to ensure effective conservations, climate change management strategies will require reliable scientific data both on the nature of climate change and on its potential impact on plants and plant communities.

Further, priority must be placed on assessing future climate conditions which impact the most vulnerable species so that current and future management actions can be most effectively targeted. Moreover, climate change - including changes longterm average conditions, variability or to frequency or society of extreme events — will affect vegetation from genes to species to ecosystems, past changes in climate have been recorded and future protections are available that can provide asarting point for assessing the type of climate stressors that will impact various vegetations management endpoints in our terrestrial and freshwater system.

Recommendations

From this review work and present vegetation problems as a result of changing climates, the following are hereby recommended:

1. Reformation of existing vegetation management activities so as to maximize climate change mitigation and adaptation opportunities.
2. Collection of information to prepare comprehensive strategies and plan effectively to deal with plant conservation.
3. Plant conservation action needs to be increased now to ensure that options are available for the future.

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