

CLIMATE CHANGE AND AEROALLERGENS IN SOUTH AFRICA

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ABSTRACT

Climate change and its effects on aeroallergens and allergic disease have been extensively studied in the northern hemisphere, but there has been a dearth of similar studies in the southern hemisphere. Aeroallergens are extremely sensitive to certain weather parameters and changes may increase or decrease their levels in the atmosphere. Climate change projections include global warming, an increase in extreme weather events and greater volumes of rain. Alterations in the carbon dioxide levels, mean temperature, relative humidity and wetting of the nine distinct climate zones in South Africa will affect the vegetation distribution, causing shifts which will disturb the balance of their ecosystems. These changes will have a profound effect on aeroallergens such as pollen, fungal spores, house-dust mite and cockroach, each of which have specific climatic requirements. Changes to climatic conditions could extend the pollen season of allergenic plants and increase the concentration of allergenic pollen in the air. Increased relative humidity and temperature could increase the levels of house-dust mites and fungal spores. There is a concerted call by northern hemisphere researchers for greater emphasis on pollen and fungal spore testing in clinical practice and for the standardised collection of aerobiological data worldwide, in order to meet the anticipated changes.

INTRODUCTION

Allergic airway disease is reported to be increasing in many urban cities worldwide.¹ This increase has been associated with climate change and an increase in aeroallergens, such as pollen and fungal spores.² The International Panel on Climate Change (IPCC), in its fourth synthesis report of February 2007 notes the 70% increase in greenhouse-gas emissions during the years 1970-2004, which has increased global temperatures.³ Increased temperatures and increased levels of carbon dioxide (CO₂) impact on plants, potentially advancing and extending the pollinating season of allergenic plants.⁴ Plants require carbon for photosynthesis and the increased availability of carbon from higher levels of CO₂ in the atmosphere is advantageous to their growth and pollinating periods. Controlled studies of ragweed grown in glasshouses have been performed. Significant increases have been found in the growth of ragweed and the allergenicity of its pollen, when the atmospheric CO₂ levels and the timing of seed germination were manipulated.⁵ Climate changes that are expected to impact on aeroallergen levels in the indoor and outdoor air are: an increase in temperature, an increase in relative humidity, increased volumes of rain or more intense rainfall periods and extreme events such as fire and flooding. Thus allergenic pollen will be pres-

ent in the ambient air for longer periods and may be rendered more allergenic.^{6,7} Many moulds are associated with the decomposition of plants, so that an increase in plant growth could result in a larger fungal spore load in the ambient air. Flooding has been shown to increase indoor allergenic fungal levels as was evident after the Atlantic Gulf Coast hurricanes of August 2005.⁸

Climate, weather and aeroallergens

Climate and vegetation biomes are inextricably interlinked. Climate is defined as the expected rainfall pattern, average temperature and relative humidity of the seasons in a particular area, based on data analysed over many decades. Thirty years is generally accepted as a minimum time scale. Weather is the day-to-day variation in these parameters and is the result of a combination of multiple factors that include wind speed and direction.⁹

Differing weather parameters, with differences in temperature, wind direction and relative humidity give rise to micro-climates within a relatively small area, so that there may be variations within the same vegetation belt. This may affect the pollen and fungal spore profiles and the start date of the pollen season. For this reason, it is necessary to sample pollen at the coast and inland in the Cape.

High concentrations of pollen and fungal spores in the outdoor air are strongly associated with weather parameters, such as temperature and relative humidity, while rainfall removes pollen grains and fungal spores from the atmosphere. This relationship has been extensively studied in an effort to predict the start date for the grass pollinating season and to forecast pollen levels.^{10,11}

Dose response and symptoms in a changing climate

Exposure to aeroallergens may trigger allergic disease such as asthma, allergic rhinitis and conjunctivitis in a sensitised individual. The amount of allergen necessary for sensitisation is difficult to quantify, particularly as sensitising doses are not uniform within the categories of tree, grass and weed pollen or among the many fungal genera. A dose response relationship between allergic disease and exposure has been observed and it is reasonable to expect that as the atmospheric allergen load increases, so too would the severity of symptoms in a sensitised patient be expected to increase.¹²

In 1973, Davies and Smith¹¹ considered a concentration of 50 grains of grass pollen/m³ to be the minimum threshold level required to trigger symptoms in grass sensitive patients. Almost 40 years later the threshold concentration for grass pollen from outdoor sampling is believed to be as low as 4 to 12 grains/m³.¹²

Mapping of pollen and mould aeroallergens in South Africa has been confined to small areas, where pollen concentrations, start dates and seasons have been well studied. Climate changes may alter these profiles. Spring in the Cape often coincides with heavy rain¹³ which removes allergenic tree and grass pollen from the ambient air, thus relieving the symptoms of allergic rhinitis, conjunctivitis and hay fever. Should the expected drought conditions reduce rainfall in the Cape, this

protective mechanism could disappear. Thunderstorms that occur in summer rainfall areas such as Gauteng, KwaZulu-Natal and Mpumalanga may increase during the major grass pollinating period. Thunderstorms can rupture hydrated grass pollen grains, releasing millions of tiny allergenic starch granules that are easily respirable. This phenomenon has been linked to epidemics of asthma.¹⁴

Recent studies have found similar links between asthma and broken spores of *Alternaria*, an allergenic fungal spore, after thunderstorms.¹⁵ If rainfall predictions for South Africa are correct, increased rainfall in these areas, together with thunderstorms, which are a common feature of many South African summer rainfall areas, could trigger increased exacerbations of asthma in patients sensitised to grass pollen and *Alternaria* fungal spores.

Shifts in vegetation belts and extreme events

Figure 1 shows the interaction between climate change and biodiversity loss.

Allergenic pollen taxa are divided into the categories of trees, grasses and weeds and their seasons differ. The heaviest tree pollen catches in South Africa generally occur in spring and early summer, although a relatively small area of the country has been sampled to date and pollen sampling studies have mostly been confined to urban environments.

In the *Fynbos* biome, a biome that is home to a collection of woody shrubs and plants with needle-like leaves, Proteaceae behave like mini spore traps, trapping anemophilous (windborne) pollen species with their sticky anthers and occupying areas that could be seeded by allergenic grasses, if these shrubs were to disappear. The *Fynbos* biome is set to become a 'biodiversity hotspot' where projected losses suggest many *Protea* species will be vulnerable to climate change as their biome area shrinks by a projected 50-65% by 2050.¹⁶ A further confounding factor in modelling the shifts in vegetation belts, which will affect pollen and even fungal spore levels, is the observation that many pollinators, such as birds, bees, butterflies and small rodents are restricted to narrow ranges of climate zones.¹⁷ Should

these vectors disappear from the fynbos biome, as climatic changes unfavourably alter their environment, the plants they specifically pollinate will also be lost. This again, would provide an advantage to wind pollinated plants, like grasses and allergenic weeds.

Climate and aeroallergens

As long ago as 1947 David Ordman, a tireless researcher, was aware of the effects of climate and different vegetation belts on respiratory diseases in southern Africa. Ordman carried out extensive studies, including pollen sampling in Johannesburg and a careful examination of skin-prick testing frequencies in South Africa, Namibia and Zimbabwe. Although the provinces of South Africa have changed since he researched regional differences and the effect of climate on aeroallergens, the vegetation belts and climate biomes have not. He distinguished between seasonal and perennial hay fever and urged his medical colleagues to carry out a pollen survey of South Africa by means of pollen sampling.¹⁸⁻²⁰ This suggestion was heeded by Professor Eugene Weinberg, who monitored pollen and fungal spore levels for his Allergy Clinic patients at Red Cross Children's Hospital for 30 years.

Pollen mapping in South Africa

Pollen monitoring is carried out by aerobiologists to obtain a 'pollen count' or the number of pollen grains or fungal spores in one cubic metre of air, in order to measure the health risk or the likelihood of symptoms of hay fever, conjunctivitis, rhinitis or asthma occurring in sensitised patients. Long-term aerobiological data exist for the Western Cape only, in suburbs at the coast, inland and close to Table Mountain, while shorter studies have been carried out in Gauteng (Pretoria, Johannesburg and Vanderbijlpark) KwaZulu-Natal (Durban and Richard's Bay) and Mpumalanga (Secunda). Grass was found to be the major pollen allergen in most cities, while subtropical Durban, a coastal city, had the highest fungal spore load.²¹

No published data on pollen sampling exist for Bloemfontein, but skin test frequencies have identified grass and maize as important allergens.²² As Bloemfontein

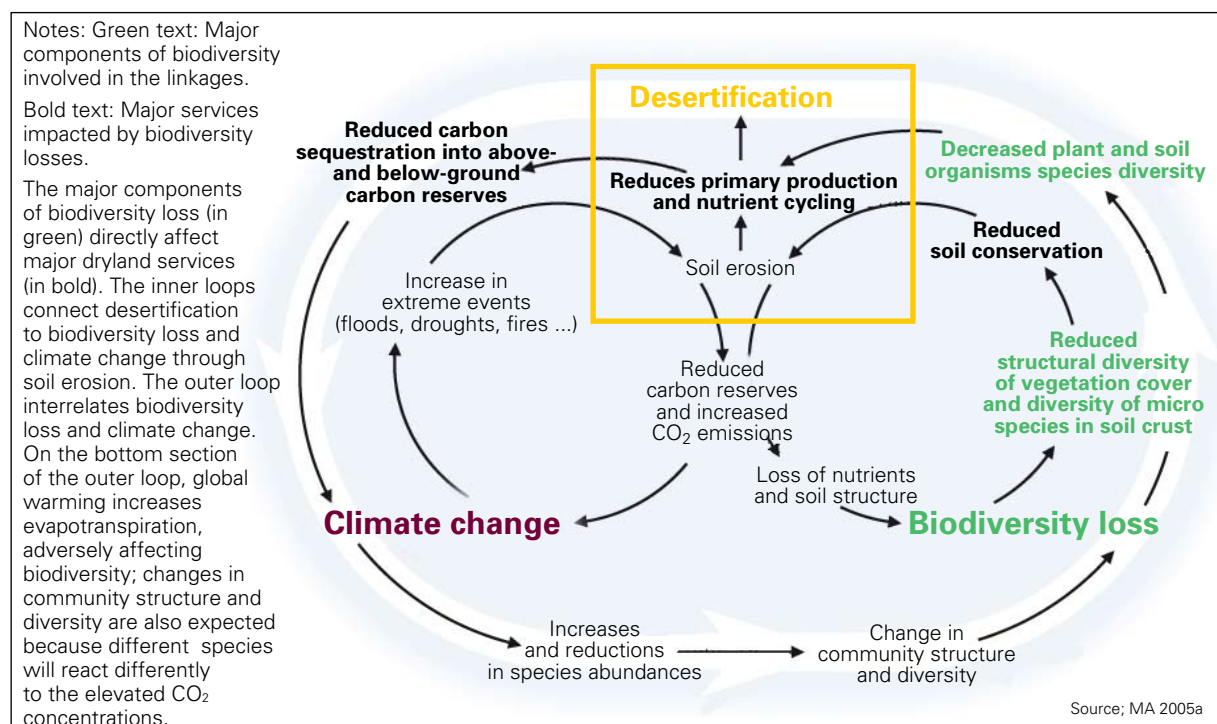


Fig.1. Linkages and feedback loops among desertification, global climate change and biodiversity loss.

is an inland city located in the Grasslands biome, it is to be expected that grass would be an important aero-allergen. Sensitivity to maize is interesting as maize pollen, *Zea mays*, is a large pollen grain, but under windy conditions may travel distances of up to 180 km.²³ Considering that grass pollen is limited to 80 km from its source,¹³ this has important implications for sensitisation, particularly during stormy weather.

POLLEN ALLERGENS

Pollen of each of the following groups has its own profile, peaking in pollen seasons prescribed by the climatic conditions of the biome in which it grows and fluctuating according to changing weather parameters. Pollinating months for pollen allergens in the different regions in South Africa are shown in the pullout table in the middle of this journal.

Tree pollen

Allergenic trees that pollinate in spring are largely alien species that have been introduced to South Africa, such as *Platanus* (plane), *Quercus* (oak), *Myrtaceae* (eucalyptus), *Cupressus* (cypress), *Alnus* (elm) and *Olea europaea* (olive) (Fig. 2).

Indigenous trees include *Olea capensis* (olive) and *Rhus* (karee).²¹

Fire and drought destroy trees and skew the balance between trees and savanna, a competitive relationship that is always unstable in a Savanna biome. Arid environments that are exposed to fire favour grasses.^{24,25} Therefore it is possible that in an area that is predicted to become increasingly arid, such as the South Western Cape with its constant threat of veld (field) fires, grass pollen levels could increase as trees, their competitors, are burnt.

Grass pollen

Many allergenic grasses have been introduced to South Africa and naturalised. While further studies are required in order to identify the major grass allergens in the different biomes of this country, some indigenous grasses have been studied. *Eragrostis curvula*, kikuyu (*Pennisetum clandestinum*) and buffalo (*Stenotaphrum secundatum*) have been shown to be major aeroallergens.²⁶ The grass pollen season in the winter rainfall area, such as the Mediterranean climate of the South Western Cape, is from September to December, with the peak pollinating month occurring in October. This coincides with the pollination of species such *Cynodon dactylon* (Bermuda grass), *Avena barbata* (wild oat), *Lolium temulentum*, (darnel grass) (Fig. 3) and *Lagurus ovatus* (hare's tail). In summer rainfall areas, the grass



Fig. 2. A 2000-year-old olive tree in the Garden of Gethsemane.



Fig. 3 Pollinating rye grass.

pollen season runs from October to December or even later, depending on the timing of the first summer rains. In Gauteng, the dominant grasses are *Themeda triandra* (rooigras), *Eragrostis* sp., *Hyparrhenia hirta* (thatching grass), *Sporobolus* and *Aristida* sp.²¹

All of these grass species have specific requirements in terms of temperature, CO₂ levels and rainfall. Extreme events, like floods, fire or very high levels of CO₂ could extend the pollinating season of these allergenic grasses, rendering them more allergenic and advancing the start date of the grass flowering season.

Weed pollen

Weed pollen levels have not been found to be as high as those measured in Europe and North America, possibly because ragweed has not been identified from pollen sampling studies in South Africa. The most commonly occurring weeds are: *Chenopodiaceae* (goosefoot), *Platanus* (English plantain) (Fig. 4), *Urtica* (nettle), *Taraxacum* (dandelion), *Myricaceae* (waxberry) and *Tagetes minuta* (khakibos).²¹

In Mpumalanga there are large stands of cosmos. This genus belongs to the family Asteraceae and is insect pollinated and it is an exception to the rule that states that allergenic plants are invariably wind pollinated. It would be wise to add Asteraceae to the skin-testing profiles of patients in Mpumalanga, as significant concentrations have been identified during pollen sampling (Berman – unpublished data).

Fungal spores

Fungal spores or moulds are present in large numbers in the indoor and outdoor air and grow readily on organic material, especially decomposing plants and leaves. Although moulds thrive at low temperatures they usually require high levels of relative humidity. The fungal spore load in outdoor air peaks during the spring and autumn months when optimum conditions of temperature and relative humidity occur. An audit of skin test frequencies in Cape Town identified *Alternaria* as the major fun-

gal allergen in a population of children with respiratory symptoms, but *Aspergillus*, *Cladosporium* and *Epicoccum* were also important sensitising fungal spores.²⁷ A study that examined the recurrent admissions to an intensive care unit of children with acute severe asthma found a higher incidence of sensitisation to *Aspergillus* and *Cladosporium* in a subgroup, the 'seasonal' group than in the control group, whose admissions did not form a seasonal pattern.²⁸

Moulds are far smaller in size than pollen grains and high levels of allergenic mould spores in the outdoor or indoor air pose a risk for asthma and allergic rhinoconjunctivitis for sensitised individuals. It is important to interpret pollen and fungal spore concentrations in the atmosphere. As with pollen taxa, the sensitising doses for various moulds vary, so that while 100 spores/m³ in the outdoor air is considered to be a health risk for fungal spores such as *Alternaria* and *Epicoccum*, the health risk for *Cladosporium* is 3000 spores/m³.²⁹

In recent years flooding has occurred in Botswana, Mozambique and Zimbabwe. The December 2010 - January 2011 floods in South Africa were linked to the *La Nina* effect.¹³ The floods in many provinces, particularly KwaZulu-Natal, Gauteng and North West Province also flooded buildings. Interventions of the post-Katrina studies which focused on reducing the high indoor concentrations of mould spores included a thorough drying of buildings, cleaning with diluted household bleach and advice that cleaning and rescue teams be fitted with facemask respirators with filters.³⁰

House-dust mite

House-dust mite levels in the indoor air are significantly associated with relative humidity and temperature.³¹ Ordman observed the differing distribution patterns of patients with perennial respiratory allergy. He noted the prevalence of house-dust mite allergy in coastal as opposed to inland areas and examined the climate factors in these two groups, paying particular attention to temperature and relative humidity.³² Collaborative studies between the Allergy Clinic at Red Cross Children's Hos-



Fig. 4. English plantain.

pital and the Allergy Diagnostic and Clinical Research Unit (ADCRU) at the University of Cape Town Lung Institute, confirmed the prevalence of house-dust mite in Cape Town.^{31,33} *Dermatophagoides pteronyssinus* was found to be the most important house-dust mite in this area. Studies in inland areas have confirmed that house-dust mite sensitisation is higher in coastal areas, where mean relative humidity levels are higher and lower in inland areas and at higher altitudes.³⁴ If mean relative humidity levels change as predicted, house-dust mite could become endemic in areas where it has not previously been considered to be a major allergen.

The case for cockroaches

Cockroaches are found in many areas of South Africa, particularly in ports.

Allergy to cockroach in South Africa has been studied (Potter *et al.*³⁴) and the incidence in asthmatic children was found to be 40%. The most commonly occurring cockroach species are the German *Blatella germanica*, the American species, *Periplaneta Americana*, and the oriental *Blatta orientalis*. The distribution of these different species seems to be associated with relative humidity as no positive reactions to *Blatella germanica* were found in asthmatic patients in warm and humid Durban, but this species was an important allergen in Pretoria.³⁵

In Bloemfontein, an inland city in the Free State, with low relative humidity, *Blatella germanica* skin-test frequencies predominated.³⁶

Pollution and aeroallergens

The role of pollutants in increasing symptoms of respiratory allergy has always been contentious because of the difficulty in carrying out controlled studies in an outdoor environment where there are many confounding factors. The incidence of respiratory disease has been shown to be higher in urban than in rural environments and this has been attributed to a westernised lifestyle, urbanisation and high levels of exhaust fuel.³⁷⁻³⁹ Increasingly, researchers are studying the interaction between pollen and pollutants and comparing adsorption levels of pollutants onto the surface of pollen grains from urban and rural areas.^{40,41} Climate change factors, such as increased temperature and CO₂ levels have added further variables to the levels of sensitisation to aeroallergens in urban areas.

PROJECTED IMPACTS OF CLIMATE CHANGE ON ALLERGIC DISEASE

Climate changes for South Africa are difficult to predict, especially with regard to wetting, or rainfall (personal communication – Climate Action Partnership, 2011, Centre for Biodiversity Conservation, Kirstenbosch, Cape Town), but broadly speaking, heavier rainfall is predicted for the eastern half of the country, while drought or lower rainfall threatens the Succulent Karoo and the South Western Cape.

Greenhouse-gas emissions are expected to raise the mean temperature in the interior, with expected temperature increases of 2-3°C. Temperatures in coastal areas are expected to be less affected and are expected to increase by 1-2°C.³

The massive increases in atmospheric CO₂ levels, as a result of human activities, will alter pollen seasons in terms of their length and the start of the pollinating season of many plants, which will in turn, impact on allergic disease. (Figure 5 shows the CO₂ emission concentrations of various countries.)

Sensitisation to pollen and other aeroallergens could in-

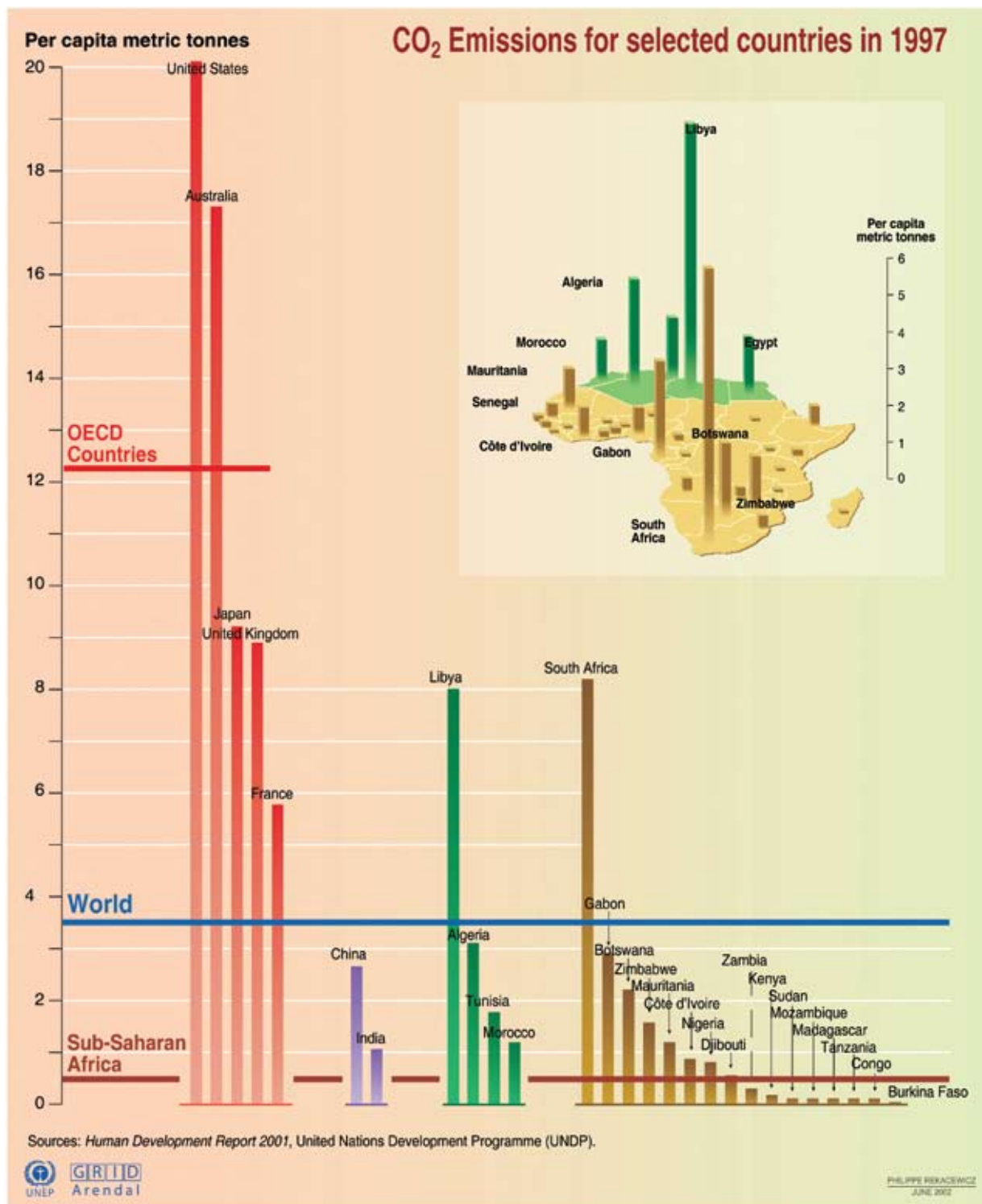


Fig. 5. CO₂ emissions of various countries.

crease because of the expected higher pollen concentrations and longer seasons of allergenic pollen.⁴²

Improved pollen monitoring of pollen and mould concentrations in the ambient air is being mooted.⁴³⁻⁴⁵ In the USA, six environmental indicators for climate change have been identified. Pollen concentration is one of these indicators. English *et al.*⁴⁵ have advocated that pollen monitoring stations be increased.

This view is shared by the European Respiratory Society. In its position statement on climate change it stressed the need for changes in pollen concentrations to be monitored and more pollen monitoring stations to be created.¹ As both the USA and Europe have extensive pollen monitoring systems already in place, this

indicates the importance of pollen sampling in efforts to adapt to the anticipated increase of allergic disease.¹

Pollen concentrations cannot be measured using the remote sensing and satellite imagery that is in use for other disciplines, such as meteorology.

The Global Earth Observation System of Systems is a worldwide data gathering process that has been formed to assist the international community with the management of natural and man-made disasters. One of the nine 'societal benefit' areas of this system is Health, which has been divided into three parts:

Health – Aeroallergens

Health – Air Quality

Health – Infectious Diseases.⁴⁶

It is for the category of Health – Aeroallergens that good pollen network systems are needed.

FUTURE RESEARCH

The White Book of the World Allergy Organisation (WAO) sets out data indicating that allergy is a major global health issue and urges an evidence-based approach to the management and treatment of asthma. Two recommendations in this approach are:-

- 'confirmation of allergy and identification of causative allergens are crucial to correctly manage allergic diseases.'
- 'skin tests should include relevant allergens and the use of standardised allergen extracts.'⁴⁷

South Africa urgently needs pollen sampling studies in areas where pollen profiles have not been researched in order to identify the relevant allergens of individual cities. Warming has been shown to be higher in cities than in rural areas due to a number of factors, which include industrial activity, and the removal of shrubs and trees. Many South African cities have been planted with alien, often allergenic trees, like plane, oak, olive and cypress.

South African studies have shown a higher prevalence of asthma and allergic disease in cities than in rural areas in populations matched for ethnicity and socioeconomic status.³⁷⁻³⁹ It is therefore practical to concentrate studies on the major cities in South Africa so that profiles of major aeroallergens in these cities may be established.

In addition a national database could be set up, where skin-prick and ImmunoCap RAST frequencies could be audited, in state and private allergy clinics. In this way, locally occurring allergenic pollen and its effect on allergic disease could be tracked and aeroallergen profiles for South African cities could be assessed. Clinicians would be greatly assisted if they were able to consult a database that listed their local pollen and fungal spore profiles and their pollinating seasons.

Collaborative evidence-based studies which bring together allergologists, climatologists, botanists, aerobiologists and epidemiologists to monitor the interaction of climate change on allergic disease are clearly needed.

Acknowledgements

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Botanical images (Figs 2-4) courtesy of Mark Berman.

Declaration of conflict of interest

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1. Log on to the Secure Members Only section at www.allergysa.org by entering your username and password.
2. Click on **My Practice** and then under **Update my Details**. Add any relevant information (HPCSA number, email address, etc.) Click **Save** on each page as you complete it before moving to the next page (e.g. email address is on Communications page while HPCSA number is on Biographical page). Once details have been updated, please email update notification to admin@allergysa.org for our records.
3. At the top of the webpage, click on **My CPD** to get to the questionnaires.
4. Click on the issue you want and answer the questionnaire. If you need to read the articles first, click on **View all articles** and follow the links (*View, Click here to read more, Proceed to questionnaire*).

5. You are allowed two attempts to answer the questionnaire, and you must get 70% correct to gain 3 continuing education units (CEUs – the new name for CPD points).
6. Click on **My CPD Home** on the left of the questionnaire to see your points. Under My Points, click **Show breakdown** and then **Certificate** if you want to print your certificate immediately. You can also print your certificate at a later stage if you prefer.

Please note that questionnaires can be answered at any time during a 2-year period. Once you have answered the questionnaire, it no longer appears on your CPD home page, but you can see your points and status by clicking **View all articles**.

NB The new website will archive CEUs (CPD points) from the November 2009 issue onwards. If you require a certificate for points gained from March to August 2009, please contact Anne Hahn, tel 021-511-2614, email annehahn@mweb.co.za.

If you are not an ALLSA member and would like to become one please contact the ALLSA office 021-447-9019, or admin@allergysa.org.

Ethics

Current Allergy & Clinical Immunology has been accredited for Ethics CPD points – 3 points based on four ethics articles published in 2010. To access the articles and questionnaire, go to *Ethics Section* on **My CPD**.