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WHITHER SUSTAINABILITY IN A CHANGING WORLD? with considerations on the future growth of Botswana

INAUGURAL LECTURE

BY

Professor Susan Ringrose

24th August 2011.

Centre for Continuing Education, University of Botswana

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Preface to the Professorial Inaugural Lecture Series

Professorial inaugural lectures are part of our engagement strategy and outreach service as they afford the University through its professors an opportunity to share the knowledge and experience cultivated over time with the general public. They also serve as an inspiration to our younger colleagues who are still working their way up the academic ladder.

It is my conviction that the inaugural lectures series will continue to cater for our multiple needs and purposes as an institution and a nation. They act as a resource for students, lecturers and other practitioners. They also provide critical information for planning the institutional operations and the shape and scope that the academic discourse must take across the institution.

The University of Botswana is proud that its Centre for Continuing Education (CCE) has taken over the initiative started in 1985 by the then National Institute for Research and continues to organise the lectures with untiring zeal. The purpose of this general introduction, therefore, is to attempt to invigorate this vibrant initiative and help to spur it to greater heights in an academic setting that is changing in line with the changing demands of the present day Botswana society which is making various demands on the University of Botswana. The professorial inaugural lecture series is therefore a unique response to the cry of our society whose members desire to be effective stakeholders and partners with the University of Botswana going forward.

Professor Isaac Ncube Mazonde
Director, Office of Research and Development

ABSTRACT

This presentation considers aspects of global sustainability initially in a geological context in order to provide a long-term perspective on global warming and to try and help define what is meant by 'the natural environment'. Geologically southern Africa is experiencing one of the longest warm/wet (relatively speaking) interglacial periods on record and given the perpetuation of recorded geological cycles, should soon be plunged into the next (cold-dry) glacial period. Hence since 'the environment' is constantly changing both in terms of long and short term responses to climatic variability it is relatively difficult to define 'natural capital' in realistic, long term trends, especially since the future cold period may be being ameliorated by CO_2 induced warming trends which further destabilises the climate. A further geological perspective lets us consider the apparent inevitability of global mass extinctions of terrestrial and aquatic species. This phenomenon has led to significant biodiversity declines several times during the evolution of global species. These mass extinctions were caused mainly by non-biotic factors with only the most recent extinction events being caused by the dominant global inhabitant, Homo sapiens. Humankind is believed to have emerged from the African rift area around 1.3 million years ago and has spread over the planet increasingly modifying its surface area. Accelerated development has taken place particularly since the last Ice Age when humans became increasingly sedentarised and began to develop crops and keep livestock under the relatively mild conditions of the present benign interglacial era.

Favourable climatic conditions to the present day have ultimately culminated in exponential increase in the world's population since the 1990s, with a present population of around 7 billion. Approximately 40% of the planetary surface is currently dedicated to feeding humankind.

Intensive agriculture has promoted major environmental changes by developing globally a series of agri-ecosystems which may or may not be sustainable as they (along with the rise of industries) have perturbed global biogeochemical cycles – mostly the carbon and nitrogen cycles, but also the phosphorous and sulphur cycles. These both exacerbate and are exacerbated by climate change but significantly the increased pressure on the 'natural environment' may well be decreasing the planets ability to continually buffer future change. Technological and biochemical advances promote intensive agriculture at a large social and financial cost such that increasing food (and fuel) prices are one of the major causes of increasing social instability.

The effects of these global changes are being dealt with differently in different semi-arid or tropical countries with examples of sustainability options being taken from mainly Botswana. Research in Botswana has lead to examples of changing environmental conditions over decadal time periods. These examples concentrate on rangeland change with evidence of increasing shrubland development which may be problematic for increasing the national herd size. The sustainable use of drinking water esources in Maun is also considered. However, planning for climatic variability and increased commodity costs in a country such as Botswana requires that major efforts towards attaining better food (and energy) security are essential while establishing a greater range of export commodities to keep the economy stable. While this is essential and maybe sustainable from an economic and social perspective, environmental impacts although hard to quantify, may be less sustainable.

The problem with sustainability as a concept is often the lack of baseline data against which to measure economic, social and environmental sustainability but cost increases globally and human striving for short term goals tends to ensure that the environment – or ecosystems in general suffer the consequences in a changing world.

Key words: *Sustainable growth, carbon cycle.*

Introduction

Global sustainability is an issue, which affects everyone's life, as we are all consumers of products derived from diminishing natural resources whether this is petroleum based or in the foodstuffs that we eat. This paper considers the fact that the increasingly large human population on the planet is consuming an excessively large proportion of the planetary natural wealth, unsustainably, for the most part. We look at this from the perspectives of economic growth and climate change. Firstly the spectre of climate change is viewed from a geological perspective, this is then linked to current climate trends, population growth and increasing human demands. After considering sustainable growth at a global scale, the arguments are then focussed on Botswana, and the problems of economic survival in a resource-depleted and increasingly consumer-driven world.

Definitions of sustainability

This paper focuses on sustainable development through sustainable growth with an emphasis on the carrying capacity of natural resources. Early definitions found in the Brundtland Commission Report (United Nations, 1987) identify sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Hence sustainable development is intended to be mindful of future human requirements. This ultimately led to the United Nations promoted Rio Summit (UNCED, 1992), which was pivotal in promoting a 'global consensus for sustainable development' articulated in the Earth Charter-Agenda 21. For the purposes of this paper, the main results of the Rio Summit were the:

- Convention on Biological Diversity (reductions in biodiversity loss)
- Forest Principles (sustainable use of forests)
- Framework Convention on Climate Change

While the focus of the Rio Summit considered environmental issues and the use of the environment, the absence of human oriented concerns particularly those pertaining to poverty were downplayed. Hence the overwhelming need to put humans back into centre-stage, particularly with respect to human-environment interactions, was recognised through the Millennium Development Goals (2011). These provided a set of objectives which were intended to be attainable within a given timeframe (to 2015). One in particular, Goal 7 was aimed at ensuring environmental sustainability through reducing biodiversity loss and ensuring safe drinking water and basic sanitation for the majority of the global population. While well intended, these global proclamations require significant international funding and the support of all sovereign states and so may not be achieved.

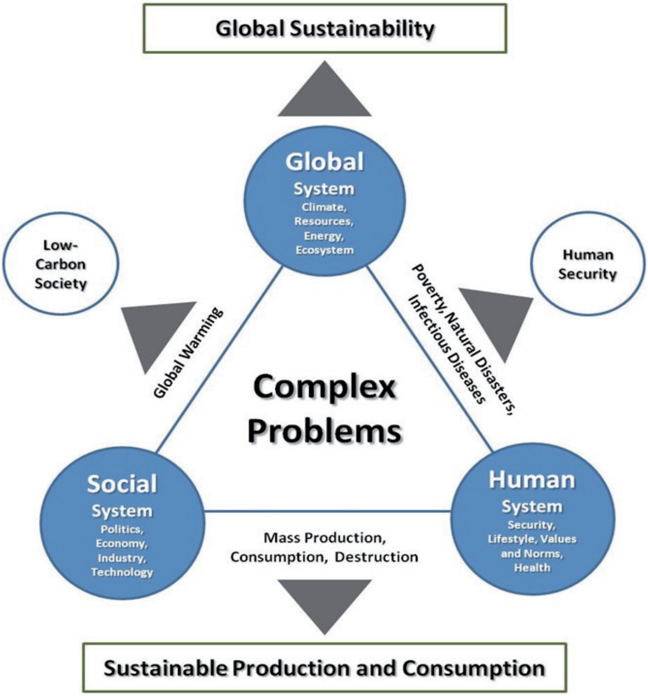

Figure 1: Elements of sustainability incorporating sustainable growth (e.g http//:en.wikipedia.org/wiki/Sustainability)

The whole question of sustainable growth is extremely complex and involves the inter-relationships of a number of diverse aspects (Figure 1). The economic-political capital that basically incorporates aspects of the social system can be seen to interact with the social-anthropological or human system. This is currently leading us into major mass production, over consumption and destructive or war-like tendencies, which need to be overcome if possible, in favour of sustainable production and consumption. The global system comprises climate, energy natural resources and ecosystems, which are currently under exploitation from economic-political capital. This has led us to ecosystem decline and global warming, when it would be more desirable to orientate productivity towards lowering our carbon output. The global system interacting with social-anthropological elements is tending to exacerbate poverty, natural disasters and a range of infectious diseases while human security is a more desirable goal.

In this paper we are looking at the possibility or otherwise, of achieving sustainable economic growth from an environmental or natural resource perspective, encompassing mostly non-renewable resources. The questions to be addressed here include:

- Timeline issues: by definition is all sustainability long term? – Or are we looking at issues over 20, 50, 200, 2000, or a million years? What are the data baselines or timelines against which sustainable growth can be measured?
- Given so much modification by humankind, what do we mean by 'the natural environment' and how much change or renewable resource use can be endured by the planet?
- What are main driving forces of change?
- What are the implications for socio-economic growth in Botswana?

Climate change and biodiversity losses from a geological perspective.

From a geological perspective climate change is a natural, recurring event. Taken over the whole history of life on earth, over the past 650 million years (Figure 2)

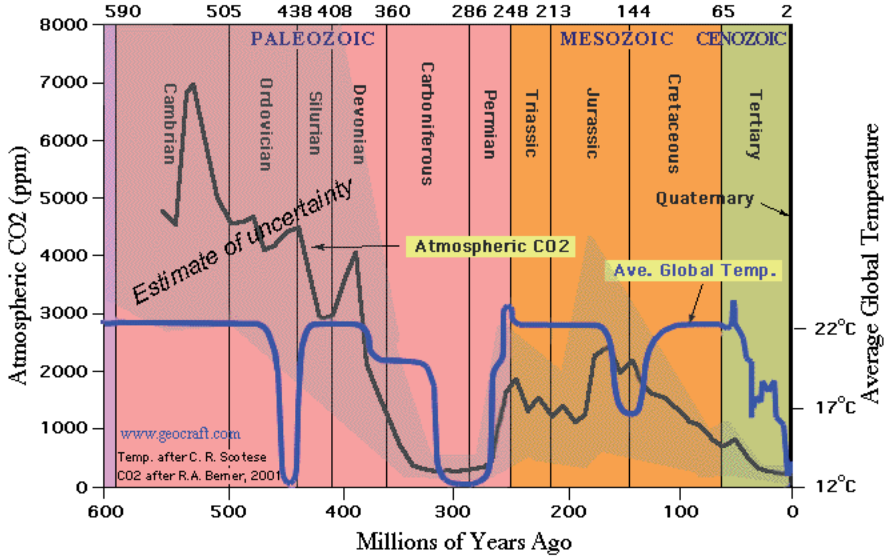

Figure 2: Atmospheric CO_2 and average global temperatures during the history of major life on the planet. (after www. geocraft.com)

It is interesting to realise that present day conditions on the planet are a result of one of the lowest CO_2 concentrations ever and are among the coolest conditions ever experienced. Globally CO_2 drops and the temperature cools down when plant life is abundant, as it has been for the past 60 million years. Between 350 and 650 million years ago, planet earth was generally considerably hotter than now with atmospheric concentrations of CO_2 averaging around 3000 ppm. During Carboniferous times, about 300 million years ago plant life was evolving so temperatures and CO_2 levels dropped accordingly. Later hot desert type conditions prevailed with higher temperatures and moderate CO_2 levels (ca. 1500 ppm) These dropped again through Tertiary time until the present day as plant life once again became abundant so atmospheric CO_2 levels are now less than 500 ppm (Berger and Kothavola, 2001).

Throughout geological time a number of mass extinctions have been detected through analysis of the marine fossil record. These extinctions affected a range of lifeforms and occurred at 450, 375, 250, 200 and 65 million years before present. Analyses undertaken on marine fossil data by Rohde and Muller, (2005) established statistically that major extinctions on the planet occur on a 62 million year cycle. Rohde and Muller (2005) also indicated that over 99% of documented species are now extinct. It becomes apparent that biodiversity declines in geological terms are a feature of the planet and more so, the immediate environment. Most extinction events have occurred during times of rapid climate change while adaptations leading to evolutionary changes tend to occur when climatic or environmental changes are more gradual. However mass extinctions are often multi-causal and their causes remain largely unresolved (e.g. Herman, 1981). During rapid changes often the dominant species become extinct leaving ecological niches for new species to evolve relatively rapidly for instance when large reptiles (including the dinosaurs) became extinct at the Cretaceous-Tertiary or K-T boundary (65 million years ago). This left the planetary terrestrial environment relatively free for the evolution of mammals and other newly adapted genera, to take place during the Tertiary (e.g. Thomas, and Shackleton, 1996). Extinctions during the later Pleistocene took place as humankind found new continents to inhabit and large herbivores became prey to improved hunting techniques (e.g. Martin and Kline, 1984).
Looking at temperature changes during the last 400 000 years (the later Pleistocene and current Holocene) in southern Africa have been derived from the Antarctic Vostok Ice Core data (Petit, 1999). Figure 3

shows that the region has undergone four short periods of maximum warming (brief inter-glacials lasting about 10 000 years) interspersed by 70-80 000 years of major cooling (the dry glacial periods).

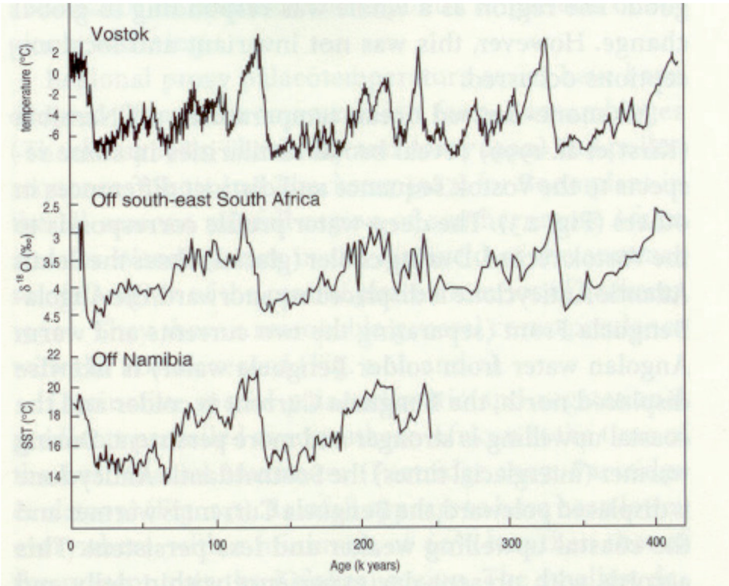

Figure 3: Temperature changes during the last 400 000 years in southern Africa - Last Glacial Maximum occurred around 18 000 years ago while the Holocene Altithermal took place around 7.7 000 years ago (Petit, 1999).

Significant here is that the cold/dry periods are typically longer and so more intense than warm/wet intervals and that we now are at the end of the last warm wetter inter-glacial (Tyson et al., 2002, Partridge et al. 1993, 1997, 1999) when humans were able to evolve and develop under relatively pleasant climatic conditions. Cooler-drier conditions might well follow soon over the next 10 000 or so years if the earth's climatic systems were to remain in a natural or unaltered state.

Speculatively, the global warming trend which we are currently experiencing could be more extreme if it were not counterbalancing a natural cooling trend.

Humankind (as *Homo spp.*) have occupied the planet for a relatively short interval and have been most successful in adapting to environmental conditions during the Pleistocene and Holocene over periods when increasingly use was made of available natural resources for protection and to hunt animals (e.g. Deacon and Deacon, 1999). In Botswana, our work has tended to concentrate on the last 100 000 years. This has included detailed analyses of calcrete deposits with their C and O isotopes to indicate wetter and drier cycles. The calcretes and silcretes precipitate towards the top of the prevalent groundwater fixing a signature which is used to interpret palaeo-environmental change (e.g Ringrose et al., 1999, 2002, 2005, 2008, 2009, 2011 and references therein). Sequences such as the following pertain to environmental change in the Lake Ngami region, and by inference, northern Botswana (e.g Huntsman-Mapila, et al, 2005), for example:

- 40-32 000 years ago – Makgadikgadi-Okavango-Zambezi basin wet conditions
- 32-22 000years ago – Alternating wetter and drier conditions in Ngamiland
- 22-27 000 years ago – Lake Ngami basin filled –wet conditions
- 18-21 000 years ago - LAST GLACIAL MAXIMUM –DRY-COOL –(regional)
- 17-14 000 years ago – warmer/wetter conditions of last (current) interglacial

The last glacial maximum is a benchmark time (Figure 3) of maximum coldness in the southern African region and was followed quite steeply by warming conditions up until the Holocene (interglacial) altithermal (7-8 000 years ago). Relatively little is known in Botswana about changing climatic conditions during the last 10 000 years. As the Holocene altithermal was a relatively recent event, locating evidence for this and possible subsequent cooling (or warming) events should be evident in recent sediments. Results from the Makgadikgadi Pans show major fluctuations in inflow reflecting climatic extremes from cold/dry to warm wet (e.g. Thomas and Shaw, 1991). Recent data indicate that the latest expression of the pan basin contained an extensive though intermittent, freshwater lake-from 8700 to around 5000 years ago implying a hot/wet climate. Now the pans are reverting to cold/dry saline lake conditions partly due to reduced inflow and changing local rainfall regimes (Ringrose et al., 2011).

It becomes interesting to realise how human beings have modified the landscape globally. Human induced land-cover changes have been particularly significant over the last 5000 years as evidence suggests that the CO_2 content of the atmosphere has increased through the Holocene, as a result of anthropogenic activities. Recently published modelling work by Stoker et al (2011) shows changes to the planetary atmosphere using mainly the Hyde 3.1 model, which incorporates the sum of increasing areas of croplands, pastures and urban areas as these spread across the planet, on a 2.5 by 3.75 degree grid. Although humans moved out of Africa and spread as hunter-gatherers through Europe and North America 100 000 years ago, serious impacts on the land surface began around AD1000 until present. Around AD1000 relatively intensive human activity was taking place mainly in Europe, particularly around the Mediterranean sea. By 1850 intense human activity had expanded to all of India, large parts of China, Africa and North America. By 2005, humans had impacted about 40% of the earth's land surface on most continents, except the Arctic and Antarctic. By 2011, these global impacts were being fuelled by the highest human density ever, as the population on the planet finally reached the seven billion mark. Recent growth has been exponential with the key tipping point of extraordinary growth taking place around 1900. Malthus (1798) and Ehrlich (1968) each separately predicted dire consequences if overpopulation was not checked. The suggestion is that humans will no longer be able to feed themselves (Figure 4) if population growth outstrips the area available for cropping and other agricultural activities. FAO and other UN agencies (IISD, 2011) tend to take the view that production systems and available agricultural land, coupled with improved technologies, will always be there to supply the increased demand. However there is considerable pressure being placed on this supply/demand relationship as the price of fossil fuel is increasing and alternative sources, though increasingly feasible, have not yet replaced fossil fuel driven farm equipment (Campbell, 2004). Our global economic systems have been based on a continual growth paradigm. Sustainable or not, substantial economic growth has taken place in most regions of the planet until the recent financial downturns in Europe and North America in 2008 and 2010.

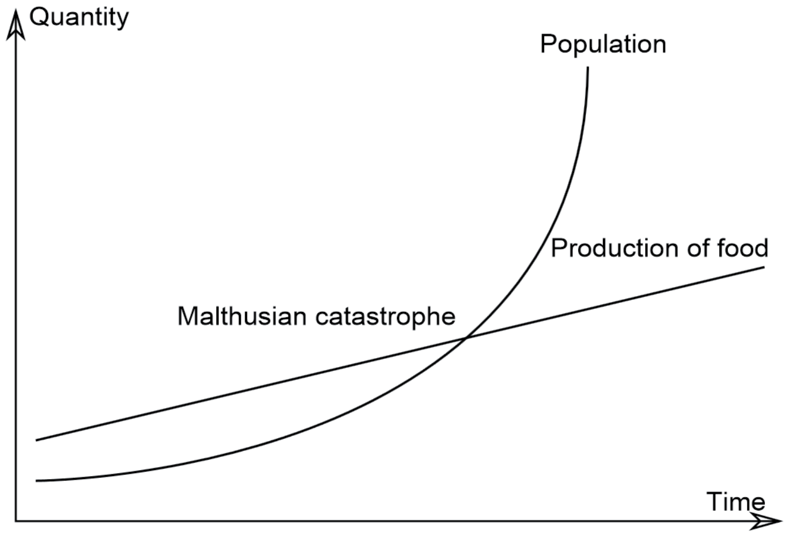

Figure 4: Possible relationships between high population growth rates and global food production (y axis) over time (x axis) (Ehrlich, 1968).

However population growth is now levelling off. What is causing population growth rate to decline and is this making any difference to global sustainability? Population data vary over the world with much of Europe and North America currently going into a population decline. In 2010 China had a population of 1 341 million, India 1 225 million, USA 310 million. Projections to 2100 show that in terms of growth India will lead global estimates with a population of 1 551 million, making it the most populous nation on earth. Comparable data show China increasing to 941 million and Nigeria to 730 million by 2100 (The Economist, May 2011). Feeding such large numbers might be problematic under fluid and expansionist economic conditions but this is now worsened by energy shortages. Hence the spectre of a Malthusian catastrophe remains with us (Fig. 4).

While fossil fuels are finite, agriculture and therefore food production falls under renewable resource use and therefore should be more malleable if enough food can be grown commercially using large scale techniques (e.g. FAO Corporate Document, 2011). Most food productivity costs, which are fossil fuel based, are rising world-wide leading to foodstuffs becoming increasingly expensive (Figure 5) and this predicament is being worsened by increases in transport costs. A further aspect of the problem lies with intensive mono-crop agriculture, which although regarded as being essential for large-scale food production, tends to de-naturalise the local environment, for instance, by changing woodland into cropland. These intensive and large scale production systems perturb the natural carbon, nitrogen, phosphorous and sulphur cycles (e.g. Leah May et al., 1999) making the planet highly unnatural or polluted, while at the same time contributing to global warming. There are also real dangers of biotechnological overuse and an increased risk of infectious diseases in chemically polluted fields due to the evolution of mutant microbial strains (fatal *E. coli* outbreak in Germany, 2011).

Before 1950 most nitrogen (N) fertilisation was bacterial/soil microbial fixing but now the predominant fertilizer is factory produced inorganic N. The largest consumer of fossil fuels in modern agriculture involves ammonia production via the Haber process.

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Figure 5: Feeding a large and demanding population is an increasing challenge as costs though fluctuating seasonally, have generally rising over recent years (The Economist, May 2011).

Inorganic N (along with phosphous and potassium) are regarded as being essential to sustain intensive agriculture. Tilman (1999) has shown that the recent intensification of agriculture, and the prospects of future intensification, will have major detrimental impacts on the non-agricultural terrestrial and aquatic ecosystems of the world. His work shows that the doubling of agricultural food production during the past thirty-five years was associated with a 6.87-fold increase in nitrogen fertilization, a 3.48-fold increase in phosphorus fertilization, a 1.68-fold increase in the amount of irrigated cropland, and a 1.1-fold increase in land in cultivation. The anticipated next doubling of global food production commensurate with global population growth, would be associated with approximately 3-fold increases in nitrogen and phosphorus fertilization rates, a doubling of the irrigated land area, and an 18% increase in cropland (Tilman, 1999). These projected changes are expected to have dramatic impacts on species diversity, composition, and the functioning of the remaining natural ecosystems of the world. These impacts will also compromise the ability of ecosystems to provide society with a variety of essential ecosystem services, similar to those currently being provided by the Okavango Delta. The largest impacts therefore are expected to be on freshwater and marine ecosystems, which run the risk of eutrophication by high rates of nitrogen and phosphorus release from agricultural fields. In aquatic environments, eutrophication can lead to loss of biodiversity, outbreaks of alien species, shifts in the structure of food chains, and the impairment of fisheries. Because of aerial redistribution of various forms of nitrogen, agricultural intensification also has the potential to eutrophy many natural terrestrial ecosystems and contribute to the atmospheric accumulation of greenhouse gases (Tilman, 1999).

Many intensive farming areas in Europe and North America now limit fertiliser use, which in addition to pesticide and herbicide restrictions are tending to revitalise the once fresh waterways at a cost. Despite all the modern agricultural inputs, improvements in biotechnology and bigger crop production systems, prices are rising globally (Figure 5). As food production costs are soaring, the net effects of increased processing and packaging, coupled with the expense of global distribution to supermarkets and restaurants, all generate approximately 50% waste relative to the initial harvest. It would appear that this proportion is excessive and could relatively easily be reduced.

A further limitation on future large-scale commercial crop production in the tropics hinges on changes in the world temperature patterns. Despite geological predictions, world temperature has increased by approximately 2-3 degrees C since the Industrial Revolution (ca. 1850) leading to increases in evapo-transpiration and the destabilisation of the atmosphere (Hadley Centre data). Increasing temperatures tend to induce an increased incidence of drought and floods, which with deceasing rainfall leads to declining crop yields (Battisi and Naylor, 2009), particularly in the tropics. They indicate, using IPCC based predictions, that higher growing season temperatures can have dramatic impacts on agricultural productivity, farm incomes, and food security. (Battisi and Naylor, 2009) used observational data and output from twenty-three global climate models to show that growing season temperatures in the tropics and subtropics by the end of the 21st century will exceed the most extreme seasonal temperatures recorded from 1900 to 2006. In temperate regions, the hottest seasons on record will represent the future norm in many locations. Historical examples illustrate the magnitude of damage to food systems caused by extreme seasonal heat and show that these short-run events could become long-term trends unless there are sufficient investments in adaptation. Interestingly the maps in this publication show minimal increased temperature for Botswana although the reasons for this are not stated.

The food crises of 2008 and 2010 demonstrate the fragile nature of feeding the world’s human population and the reactivity of world markets to seasonal shortages leading to riots especially in poorer nations. Wheat production in Russia, which provides 8% of the world’s wheat is a case in point. Poor harvests in Russia should be offset by increased exports from elsewhere (e.g. Canada), but news of poor harvests leads to panic buying and embargoes creating unnatural shortages (The Economist, September, 2010). The need for more agricultural land plus land for timber products and biofuels is also in part fuelling the felling of tropical rain forests. Recent estimates show that we are losing tropical rainforests at 2.5% per year, which if projected through time, means that there will be no tropical forests left in 40 years time (The Economist, March 2011). Rapid tree felling is particularly active in the Amazon and less so in the Democratic Republic of Congo (Knock, 2008). However following the international conventions on biodiversity and climate change there is currently a greater awareness, though few economic incentives, to promote a 'low carbon' society by preserving world's forests (for instance through the REDD schemes) and minimising biodiversity losses (Figure 1). Species losses are taking place from most ecosystems. Recent work suggests that marine/terrestrial biodiversity is decreasing rapidly as about 40% land surface is under intensive agricultural production with overall human impacts on approximately 83% of land surface, despite the growing recognition of the value of ecosystem services (Mora and Sale, 2011). The numbers of humans on the planet and their direct and indirect requirements for space is having the effect of increasing the numbers of other species threatened by extinction due to habitat loss, over-harvesting, alien species invasions, habitat alteration and pollution (Mora and Sale, 2011). The effects of climate change are more difficult to determine with any degree of certainty, as all the impacts stated above are intricately interwoven. Significantly humankind allows biodiversity losses to take place and in many cases developments, which annihilate plant or animal life, are promoted in the name of economic growth, progress, return on investments (e.g. Ramberg, 1993). The need to feed growing numbers of people is increasingly important in this age of uncertainty and food insecurity. These kinds of losses and the need to curb/control increasing growth based on factual scientific evidence has been identified by the German government who developed the GLUES (2011) project in order that certain ecological threshold limits might be identifiable in the future on a global scale.

Sustainable growth challenges currently occurring in Botswana are mainly due to various global pressures in the face of significant economic downturns. These are causing financial markets, the driving force of all growth, investment and security to become increasingly jittery therefore unpredictable. Much of the uncertainty or instability, arising particularly since the current global financial downturn, is therefore externally driven but requires those managing the Botswana economy to react creatively. The kinds of impacts, which we are currently experiencing and cannot control include:

- Increasing health care costs
- Increasing energy costs
- Increasing food costs
- Increasing education costs
- Biodiversity losses
- Raising CO_2 and climatic destabilisation
- Mining exports without processing

While other such as the increasing population (from 1.5 million in 2001 to 2.0 million in 2011 (Botswana Demographic Profile, 2012) lead to more consumer demands as the relative wealth of the country increases. Due to improvements in education and access to the media, there is a very understandable need for quality of life enhancement, hence consumerism is rife. We have, and need, more cars, more diverse foodstuffs, more electrical appliances, bigger houses, more international travel and many more, all of which are in themselves consuming ever increasing energy in terms of, for instance, fossil fuels. Consumer products are using up the nation's foreign reserves in terms of import requirements.

Estimates indicate that in terms of land-use or land cover Botswana is made up of approximately 74% rangeland, 23% protected areas, 3% urban, 0.65% cropland (estimated from Botswana National Atlas, 2001). There is a growing need to expand cropland because of rising costs and food security issues. Plans are underway, for instance, to expand intensive agriculture north of Pandamatenga using intensive farming systems and irrigated water. There is also a problem with protected areas which though large are fragmented and cannot accommodate both the wet and dry season needs of all wildlife species (R. Fynn, personnal communication). Rangeland and beef production have traditionally been most significant in Botswana leading to ideas to double the national herd. Work by Sakaran et al (2005) show that rangeland savannas such as the Botswana Kalahari, occupy a fifth of the earth's land surface. Savannas support a large proportion of the world's human population and most of its livestock and wild herbivore biomass. A defining feature of savanna ecosystems is the coexistence of trees/shrubs and grasses. The balance between these two life forms influences both plant and livestock production, and has profound impacts on several aspects of ecosystem function, including carbon, nutrient and hydrological cycles. Hence, a phenomenon such as excessive bush encroachment, coupled with increasing temperatures will tend to destabilize the ecosystem functioning of savannas such as the Kalahari thereby decreasing their intrinsic value in terms of continued rangeland productivity.

While much research has been undertaken on rangelands and beef production in Botswana, (e.g. Ringrose and Matheson, 1991, 1995, Perkins and Ringrose, 1996, Ringrose et al., 1999, Vanderpost et al., 2010) more work is needed to determine the drivers of variable rangeland quality throughout the country. The need to keep the rangelands in a quasi-natural condition, to ensure continued productivity, has been illustrated in recent work by Vanderpost et al., (2010). Landsat imagery was used to identify unnaturally generated bare soil extent as a surrogate for degradation. Results show that in 1984, about 65% of Botswana comprised bare soil as a result of prevalent drought conditions. By 1994, many of these bare soil areas had regenerated with returned seasonal rainfall, but especially in the protected areas such as the Central Kalahari Game Reserve and Chobe National Park. By 2001 most of the country was experiencing ‘moderate rangeland conditions.’ Most areas were not highly vegetated but simply ‘adequate’ in terms of prevailing conditions. It appeared from field data records that a major structural change had taken place throughout most of the Kalahari, due maybe to fires but also possibly to grazing as areas with taller trees and intermittent grassland were being converted to shrubland, with overall less grassland. Much of the semi-arid Kalahari rangeland areas are subject to bush encroachment which appears to arise particularly in areas which are heavily grazed are then subject to drought conditions (Moleele et al., 2002).

While rangeland changes might well adversely influence our ability to sustain an increased national herd, changes in water availability, though inter-related, could well have additional negative impacts. Work by Vorosmarty et al., (2000) illustrates the effects of water demand globally in relation to climate change and population pressure. These authors mapped the 'change in water re-use index' which is defined as the quotient of combined domestic, industrial and agricultural sector water demand relative to mean annual surface and sub-surface runoff accumulated as river discharge. This was as predicted by various climate change models, specifically the CGCM1/WBM model. As indicated in Fig 6, model run Sc1 indicates that the impacts of climate change alone are only significant in terms of predicted wetter or drier conditions over about 25% of the earth's surface. However, looking at population growth and its impact in terms of economic growth with increasing water demand, (model run Sc2), approximately 66% of the earth's surface is adversely affected. This impact naturally increases even more when the effects of climate change are combined with population growth (model run Sc3). An inevitable conclusion here is that when projected to all water using renewable resources, human growth and attendant resource depletion rates are much more significant than climate change impacts alone, in terms of consumption outstripping supplies. This underscores the need for a major paradigm shift if we seriously wish to use the natural resources available to us in a sustainable manner.

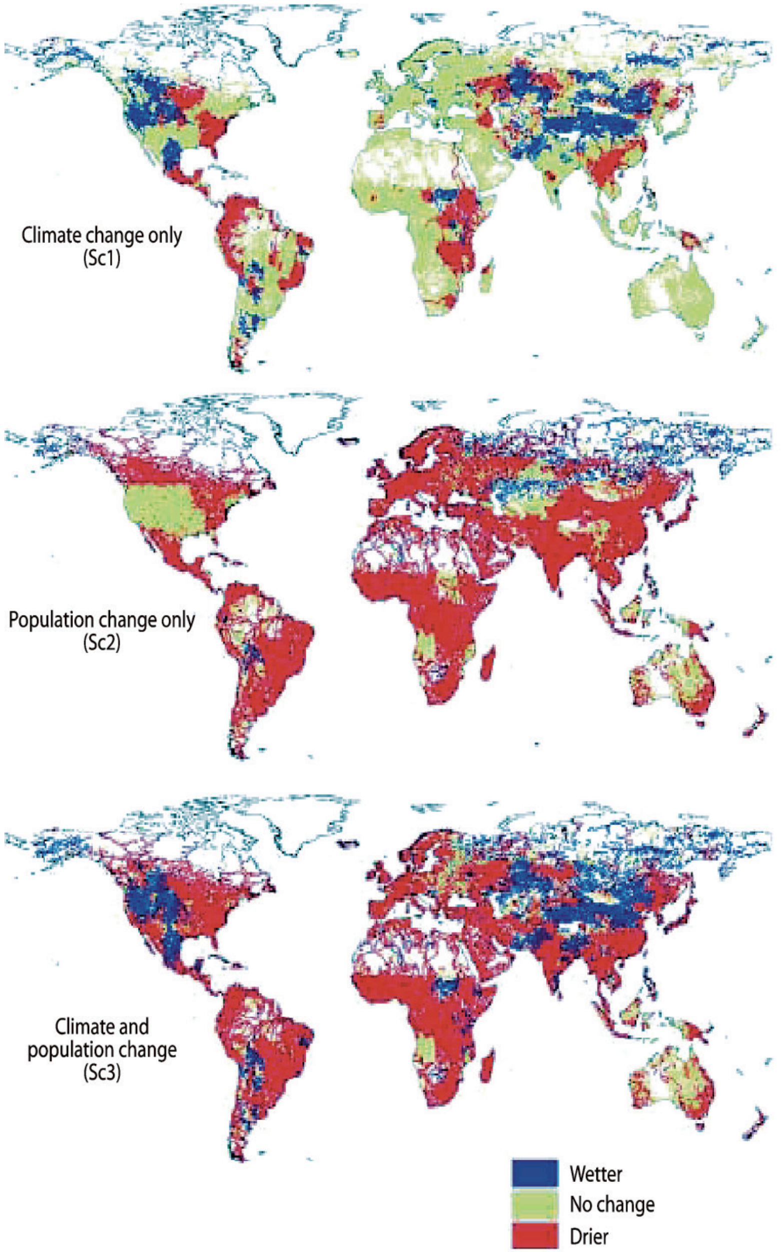
Climate change only
(Sc1)
Population change only
(Sc2)
Climate and
population change
(Sc3)
Wetter
No change
Drier

Figure 6: Predictions in overall water use in terms of the impacts of climate change and population pressure (Vorosmarty et al., 2000)

Water resource issues, like other renewable resource concerns, are extremely complex as exemplified by the water supply and demand issues in Maun, northern Botswana (Ringrose et al., 2011). Maun is a growing regional capital with a population growth rate of over 40% per decadal census period. The expansion of Maun, in addition to increases in population in the other regional centres peripheral to the Okavango Delta (such as Gumare and Shakawe) has seen increasing demand on local water supplies. With this in mind the Department of Water Affairs (2000) initiated a water supply/demand project in the mid-1990s, referred to as the Maun Groundwater Development project to determine the feasibility of supplying long term safe drinking water to Maun.

Considerable reserves were located and tested in the lower delta distributaries where abundant fresh water reserves were located (Figure 7A). However, several factors hampered the outcome of this investigation. Flood levels of the Okavango were in a cyclical dry spell during the 1990s when the investigation was carried out, such that all the lower rivers were dry. As indicated in Fig. 7A, most of the available fresh water was found in aquifers below dry riverbeds. While the cyclicity of the system was known (Figure 7B) three pump-houses aimed at providing sustainable drinking water to Maun were established within the Kunyere River. However from 2005 onwards the rivers began refilling with the inevitable result that the pump-house infrastructure became inundated and for a time unusable. Pumps had to be pulled out of the water and islands built. Maintenance was/is extremely difficult by boat such that the Maun water supply is still problematic and has been worsened as recent floods have damaged inflow pipes. Therefore the existence of water in a river does not necessarily translate into its availability as safe drinking water to the general public. Issues of infrastructure, reticulation and leakage are such that even in areas with relatively heavy rainfall and perennial streams, the availability of fresh water to the general public is not a foregone conclusion.

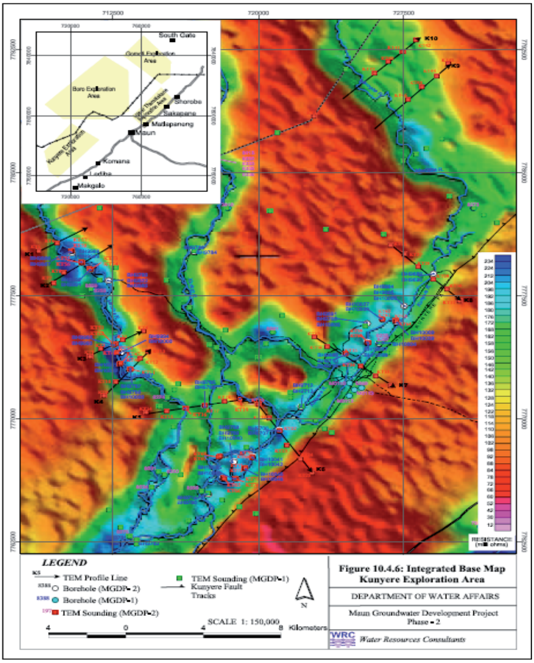

Figure 7A: Location of suitable aquifers in the vicinity of Maun (Department of Water Affairs, 2000)

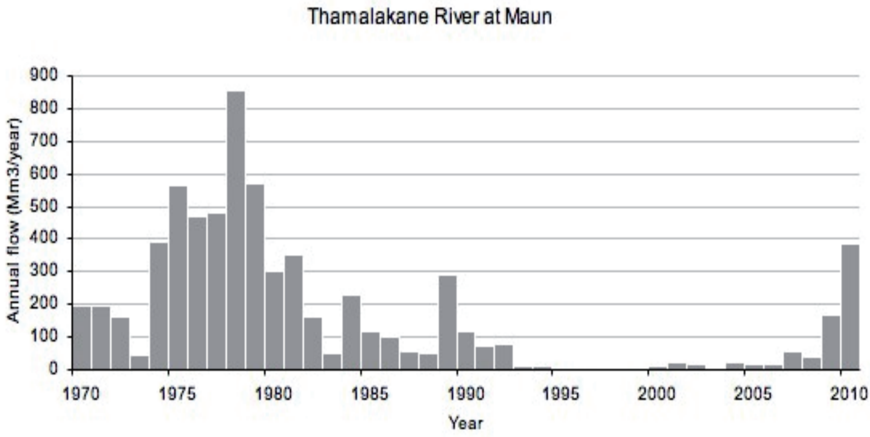

Figure 7B: Hydrograph of the Thamalakane River flow at Maun (Wolksi and Murray-Hudson 2000)

Economic growth in any country has to be well managed and the availability of resources cannot be taken for granted as the issues involving resource use are complex and multi-dimensional. Botswana finds itself embroiled in the overall global shortages of natural resources. This is resulting in unsustainable food and fuel usage, exacerbated by water deficits. The overall perspective in a changing world points to the inevitability that sustainability, while an ideal to aim for, cannot be accomplished as global systems are based on an untenable growth oriented, economic model fuelled by capitalism/democracy. Many believe that as a result of excessive growth, planetary resources are hitting a food and fuel wall. This is illustrated by recent analyses of the ecological footprint, which illustrates the extent to which humans are using up ecosystem resources (Fig. 8).

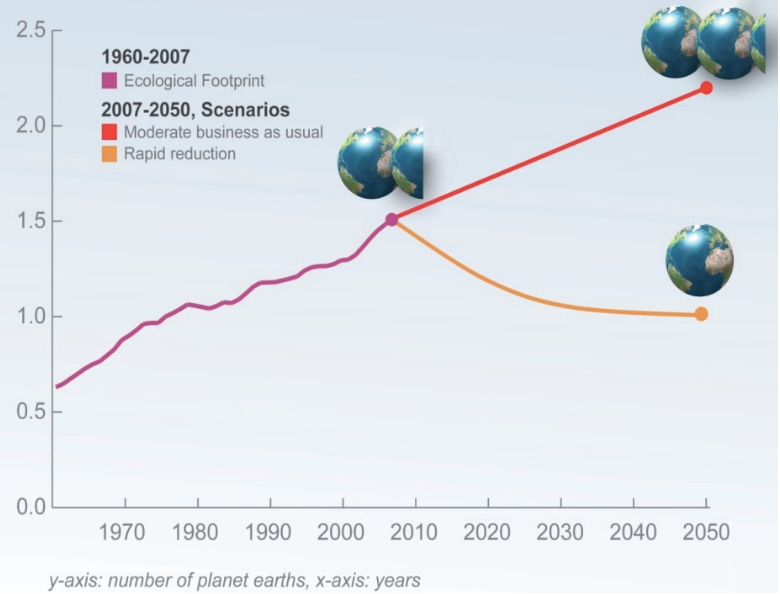

Figure 8: Modelled demand for natural resources to 2050 (Ecological Footprint Network, 2008)

Figure 8 indicates that currently humankind are using up to 1.5 times the global planetary resources in a way that is obviously unsustainable. Also indicated is the idea that it would take a rapid reduction in planetary resource use, either through population reduction and/or decreases in consumer demands, to allows us to revert to sustainable normal life on the planet. Given increases in resource use commensurate with population growth, by 2050 we will be consuming 2.2 times as many resources as the planet can sustain (e.g. Wackernagel and Rees, 2008). This is why 2050 is often stated as a 'doomesday' time for ecosystem collapse on the planet, unless something radical is put in place to divert disaster.

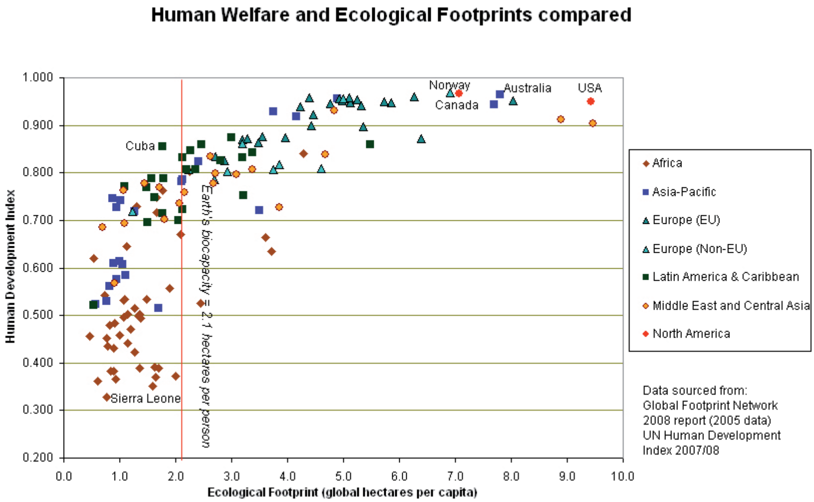

Figure 9: Human welfare and ecological footprint compared (Global Footprint Network, 2008; UN Human Development Index, 2007/8)

Figure 9 shows that the richer nations of North America and Europe are consuming between five to nine times more in terms of the global footprint hectareage than most African and many Asia-Pacific countries whose populations are normally operating at or below the earth's biocapacity which is indicated at 2.1 hectares per person. Botswana, being one of the richer therefore more highly consumptive African nations, is apparently consuming at a rate, which is only slightly higher than the 2.1 hectares per person average. But unfortunately we live in a highly consumptive world where costs are increasing rapidly. This places us at a crossroad or tipping point. We can contribute to sustaining ecological resources and help maintain global biodiversity mainly by slowing down growth or we can continue to grow and develop by consuming more and more of our natural resources, whether sustainably or not. The problem is that we are inevitably linked to global financial markets which means we need to attain more competiveness in an increasingly wealth driven and expensive world. So in reality there is little choice. Development or economic growth in Botswana, and elsewhere, is inevitable to provide a buffer against rising global costs of food and fuel. For the economy to flourish in Botswana we need to be competitive or at least increasingly self reliant as global economies flounder. We have expectations of a continually improving life-style for ourselves and our children fuelled by better education and health services and a wide range of consumer goods. For these expectations to be met we need to have a strong, self reliant economy. The nation needs to be self reliant in as many economic aspects as possible, including foodstuffs, energy and water supplies. **Table 1** indicates the kinds of activities which are ongoing or planned in the country. Such growth is essential, despite the obvious and other more subtle environmental impacts. For an economy to remain strong, foreign reserves are needed as a hedge against a downturn in the economies of trading partners and currency declines. So in Botswana as elsewhere in the world, the environment in general might be expected to suffer to some extent. It is a question of degree of impact and the implementation of informed stewardship with respect to how resources are used.

Table 1: Examples of essential development/growth activities in Botswana (2010-2015)

Development Initiative	Sector	Environmental Impact	Required aim
Irrigated land area between Pandamatenga and Kasane	Agriculture	Negative impact on wildlife migration routes	Greater food Security
Doubling national cattle herd	Agriculture	Improved management strategy comprises fencing which impedes migration routes	Greater food security
Tourism expansion	Tourism	Increasing pollution in Okavango delta and other high density tourism areas	Increase in GoB development funds
Cu/Zn mining in northern Botswana	Mineral exports	Impacts largely not known but include acidification of ground/surface water	Increase in GoB development funds
Coal powered thermal energy plant	Increased energy capacity	Increased CO_2 emissions and acidification	Energy security
Increased diamond mining	Mineral exports	Excessive use of ground water	Increase in GoB development funds

Much of the way forward is under-researched so the following are proposals for future work which might be carried out in Botswana. We need to:

1. Actively update inventories of all major ecosystems – there is a critical shortage of good data base generation in the country and good quality, easily accessible data bases
2. Develop effective ways to transform natural capital to national wealth, with minimal environmental impact
3. Ensure value added productivity in-country - over exported primary productivity
4. Design ways to properly manage tourism and hunting to ensure a well rounded product that also reduces poaching
5. Produce sustainable development indicators for Botswana which readily reflect both economic necessities and ecosystem basics – including human activities as integral part of ecosystem continuity
6. Identify tipping points in our agro/human ecological systems so that we do not destroy species of plants or animals that are rare or that we never knew existed.

We bear in mind that it should be possible in Botswana to feed, clothe and provide shelter for two million people in a sustainable way with minimal environmental impacts.

Conclusions

The following conclusions are presented.

- Timeline issues: by definition is all sustainability long term? We need the perspective of geological time to realise that climate has always changed over more extreme ranges than we are presently experiencing. Geologically speaking the planet should be cooling but is in fact warming so we are reversing a natural trend. Change is taking place so quickly that the creatures on the planet may not be able to adapt or adjust. So we may be on the verge of the sixth great extinction event. Currently there are no real baselines against which sustainable growth can be measured in Botswana.
- Given that 83% of the planet's terrestrial surface has been modified in some way by so much modification by humankind, it would be reasonable to conclude that we all live in an anthropogenic landscape but we still need to do more to provide people with basic needs. The sheer numbers of humankind at present and their desire, as middle class citizens, for bigger and better consumer products has contributed to our now hitting the food and fuel wall which is likely damaging the integrity of the planet, despite the rapid technological advances which are assisting in providing solutions.
- The main driving forces of change are financial or economic and this is becoming increasingly evident as shortages of food and fuel become more apparent. As long as the corporate world is making a profit, then the energy for change sustainable or not, will be forthcoming. In this context climate change taken in isolation is a smoke-screen. As growth

continues, concerns regarding biodiversity or overall environmental protection will need to have a greater priority.

- Botswana needs to develop in order to provide a safety net or buffer against the harsh world of economic and financial change. Hence food security, although environmentally problematic, is essential to buffer against possible shortages. Mineral extraction is also significant in order to maintain foreign reserves. Stagnation would be much worse but we need to be in a position to assess the cost of the environmental destruction that economic development entails.

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