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目 次

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DESERT TECHNOROGY IV

1997年9月21-26日、カルグーリー 西オーストラリア

日本沙漠学会

Proceedings of the International Conference on Desert Technology IV

September 22-26, Kalgoorlie - Western Australia

CONTENTS

"New Technologies for Sustainable Production in Arid Areas"

Sessions chaired by: Dr James Young, USDA, Agricultural Research Service.
Dr Igor Zonn, Russian Department of Foreign Relations, Engineering Centre of water Management, Land Reclamation and Environment.
Dr Zahid Hussain, Natural Resources Division, PARC, Pakistan

Keynote Address

Session Papers

Poster Papers

Reviewed Papers Not Presented at the Conference

"New Technologies for the Rehabilitation of Arid Areas"

Sessions chaired by: Mr Robert Svendsen, Curtin University of Technology - Kalgoorlie Campus.
Professor Toshinori Kojima, Seikei University.

Keynote Address

Session Papers

Poster Papers

Reviewed Papers Not Presented at the Conference

"Challenges for the Future"

Session chaired by: Dr Sanjay Kumar, Kyoto University

Keynote Address

Session Papers

Poster Papers

Reviewed Papers Not Presented at the Conference

Summarised by: Mr A Williams, Conference Chair
Roving Facilitator: Dr H Bieber

Workshop 1 Water: What is the role of scientists in ensuring the improvement of potable water supplies to arid areas over the next ten years?
Convenor: *Professor M Osaki* Facilitator: *Ms P Geraghty* Recorder: *Mr R Botica*

Workshop 2 Land: What changes can scientists make to improve the sustainable production in arid ares? What research in either agricultural production or land rehabilitation in arid areas is likely to produce the largest sustainable gains?
Convenor: *Dr M Sharif* Facilitator: *Mr K Pahari* Recorder: *Dr C Toderich and Mr D Fitzgerald*

Workshop 3 Air: What activities in arid areas over the next ten years will most help to improve the long term quality of the atmosphere? What is the scientists' role?
Convenor: *Professor K Yamada* Facilitator: *Dr S Kumar* Recorder: *Professor J N Shrestha*

Workshop 4 People: As scientists, how can we influence land use controls? How can we assist land users to become more involved in finding and implementing solutions to improving land quality and sustainable production?
Convenor: *Dr J Young* Facilitator: *Professor Xia Xuncheng* Recorder: *Mr R Walster*

Guest Editorial

This Special Issue of the Journal of Arid Land Studies contains the proceedings of the International Conference on Desert Technology IV, held September 22-26 at Kalgoorlie, Western Australia, in the Western Mining Corporation Conference Centre.

The papers presented at the Conference and published in these Proceedings are divided into four main themes.

1. The World's Arid Areas - Global and Regional Assessment of the Past, Present and Future
2. New Technologies for Sustainable Production in Arid Areas
3. New Technologies for the Rehabilitation of Arid Areas
4. Challenges for the Future

Within each of these themes a broad diversity of innovative technologies, new applications of technologies, and important social perspectives were presented. This reflects the multi-disciplinary approach that will be required to address the challenge of sustainable management of arid and semi-arid regions.

The invited keynote paper presentations which introduced each theme were of 30 minutes duration. The other oral presentations were of 20 minutes duration. Poster presentations were displayed for the duration of the Conference in the foyer of the Convention Centre. A two hour session of the Conference was allocated to the poster displays. Workshops on the general theme "Inventing the Future" were held on the Thursday evening of the Conference and recommendations from the workshops were taken forward to a plenary session on the following Friday morning. The workshop recommendations have been summarised by the Conference Chair, Adrian Williams, and included in these proceedings.

The draft manuscripts of papers (except keynote presentations) were reviewed by at least one anonymous reviewer prior to the Conference. Revised versions of accepted papers were then resubmitted prior to or during the Conference. If the manuscripts were revised satisfactorily, they were accepted for publication. There were a number of papers that went through the review process and were accepted, but could not be presented at the Conference. This was for a number of reasons, but usually because the authors could not get to Kalgoorlie in person. The Editorial Panel felt that these papers were worthy of publication and have thus included them in these proceedings as "Reviewed Papers Not Presented at the Conference".

In relation to these papers, the Chair of the Editorial Panel wishes to apologise to *S Matsuda, T Sano and Y Okano*, whose excellent paper "Numerical Simulation of Ascending Current for Artificial Rainfall" was accepted for the Conference as submitted and should have been included on the program. However, it was omitted from the program due to an error on the part of the Chair of the Editorial Panel, and that is the reason it was not presented at the Conference.

The Conference Editorial Panel acknowledges the vital contributions from the following reviewers:

Australia
Mr Martin Anda, Remote Area Developments Group, Murdoch University
Mr Gary Bastin, CSIRO Division of Wildlife and Ecology
Ms Gay Bradley, Senior Environmental Scientist, Kalgoorlie Consolidated Gold Mines

Mr Philip Commander, Water and Rivers Commission, Western Australia
Associate Professor Alan Graham, Western Australian School of Mines
Mr Steve Roberts, Senior Anthropologist, Goldfields Land Council
Mr Richard Smith, Remote Sensing Services, Department of Land Administration
Mr Phil Stanley, Landscaping and Revegetation Consultant, Kalgoorlie
Mr Robert Svendsen, Curtin University of Technology - Kalgoorlie Campus

USA
Dr James Young, USDA, Agricultural Research Service

Russia
Dr Igor Zonn, Eng Centre of Water Management, Land Reclamation, and Environment

December 23, 1997, The Conference Editorial Panel
Brian Fergusson - Chair
Adrian Williams
Gerry Bradley

DESERT TECHNOLOGY IV
FINAL PROGRAM - 1997

Sunday 21 September

1800	Registration and Welcome Reception

Monday 22 September

0730 - 0830	Registration
0830 - 1000	Opening and Overview of the World Situation
1000 - 1015	Morning tea
1015 - 1220	Morning Session: *'The World's Arid Areas - Global and Regional Assessment of the Past, Present and Future*
1220 - 1245	Discussion session with a panel of the morning's speakers
1245 - 1330	Lunch
1400 - 1800	Field Tours
1830 - 1930	Dinner
1930 - 2125	Evening Session: *'New technologies for sustainable production in arid areas'*
2130 - 2145	Discussion session with panel of the evening's speakers
2145 -	Social hour and informal discussions at the Mercure Hotel Plaza

Tuesday 23 September

0830 - 1300	Morning Session: *'New technologies for sustainable production in arid area'*
1305 - 1330	Discussion session with a panel of the morning's speakers
1330 - 1430	Lunch
1430 - 1600	Poster Paper Session
1600 - 1615	Afternoon Tea
1615 - 1810	Afternoon Session: *'New technologies for land rehabilitation'*
1815 - 1830	Discussion session with a panel of the afternoon's speakers
1930 -	Conference Dinner with Guest Speakers Mrs Kathy Finlayson and Mr Ian Herford

Wednesday 24 September

0830 - 2200	All day tour to livestock rearing properties ('Stations') in the North Eastern Goldfields, with dinner at the old mining town of Kookynie

Thursday 25 September

0830 - 1305	Morning Session: *'New technologies for land rehabilitation'*
1310 - 1330	Discussion session with a panel of the morning's speakers
1330 - 1430	Lunch
1430 - 1815	Field Tours
1830 - 1930	Dinner
1930 - 2100	Evening Workshop Sessions
2100 -	Social Hour and informal discussions

Friday 26 September

0830 - 1050	Morning Session: *'Challenges for the future'*
1050 - 1110	Discussion session with a panel of the morning's speakers
1110 - 1130	Morning Tea
1130 - 1320	Plenary Session and Conference Recommendations
1325 -	Close of Conference

Opening Address

Adrian WILLIAMS - Conference Chair

Delegates,

It is my honour and pleasure to welcome you all on behalf of Professor Toshinori Kojima and Dr James Young, the co chairs of Desert Tech IV.

I am pleased to see so many people from so many countries have trekked all the way to Kalgoorlie. I trust that you will all find your week stimulating, thought-provoking and rewarding.

The conference has been made possible by our generous sponsors, supporters and dedicated international and local organisers.

It is my pleasant office to thank :

AusAid, Federal Department of Foreign Affairs and Trade
Department of Commerce and Trade, WA
Carnarvon Regional Office, Agriculture WA
Water Corporation of WA
Perth Diocese of the Anglican Church of Australia
Goldfields Esperance Development Commission
Curtin University of Technology
Scania Australia Pty Ltd
Association of International Research Initiatives for Environmental Studies
Japanese Environmental Agency
Ansett Airlines
WA Tourism Commission
Mercure Hotel Plaza
Palace Hotel
Goldrush Tours
National Australia Bank
Kalgoorlie Consolidated Gold Mines
Kundana Gold Pty Ltd
Business Enterprise Centre
Snap Printing
Reynolds Graphics
Pat Leighton Chartered Accountant
Hon Mark Neville

Our international committee members, who helped provide direction and suggestions in the form this conference should take, and publicised the conference in their countries are:

Dr Herman Bieber, Engineering Foundation, USA
Dr James Taranik, President, Desert Research Institute, Reno, USA
Professor Xia Xuncheng, Institute of Desert Research, Lanzhou, PR China
Professor Yukuo Abe, Tsukuba University, Japan
Dr Igor Zonn, Senior Vice President, National Committee for UNEP, Moscow, Russia

Dr Zahid Hussain, Director, (Water Resources), Pakistan Agricultural Research Council, Islamabad, Pakistan
Dr Sanjay Kumar, now of Kyoto University, Japan
Professor Satoshi Matsumoto, the University of Tokyo, Japan
Mr Matsuo Kubota, Kubota Corporation, Tokyo, Japan
Dr Ron Hacker, President of the Australian Rangeland Society, Dubbo, Australia

The Kalgoorlie organisations that have arranged the conference are :
Goldfields Esperance Development Commission (GEDC)
Curtin University of Technology - Kalgoorlie Campus
Kalgoorlie Arid Landcare Inc
In collaboration with the Engineering Foundation, USA.

The local organising committee members are:

Mrs Corene Haffner, Corene Haffner Public Relations
Dr Brian Fergusson, Editorial Panel Chair, Curtin University of Technology - Kalgoorlie Campus
Mr Phil Stanley, Horticultural Specialist
Mrs Irene Montefiore, Manager, ABC Radio, Kalgoorlie
Mrs Marion Cahill, Tour co-ordinator, Mariana Partners
Mr Bill Mason, GEDC

Who were assisted and advised by

Professor David Spottiswood, Director, Curtin University of Technology - Kalgoorlie Campus
Mr Rob Walster, Chief Executive Officer, GEDC
Mr Bob Svendsen, Director, Vocational Education and Training, Curtin University of Technology - Kalgoorlie Campus
Mrs Kathy Finlayson, Pastoralist, and Chair of GEDC Board
Mr Gerry Bradley, Kundana Gold Pty Ltd
Mrs Alison Roberts, GEDC, in fact the whole staff of GEDC
Ms Susan Harris, now of the Education Department, Perth
Mr. Hugh Gallagher, Director of the Chamber of Commerce and Industry, Kalgoorlie
Mr. Tim Funston, Mr Steven Tonkin, Pastoralists
Members of the North East Goldfields Land Conservation District
Students of the Diploma of Applied Science (Environmental Technology), Curtin University of Technology - Kalgoorlie Campus

I owe them all a debt of gratitude for all the support and hard work that they have put into the conference, and I am so pleased to see so many of the International and local committee attending the conference. (They are the ones that made it happen.)

I am very pleased to welcome our keynote speakers

Dr Victor Squires, Rangeland Consultant, Adelaide
Dr Graeme Robertson, CEO of Agriculture WA
Mr. John Mc Lain, Principal, Resource Concepts Inc., Carson City, USA
Mr. Clive Malcolm, Consultant, Australia

I am also pleased to welcome Dr Herman Bieber, who represents the Engineering Foundation, USA, which initiated this series of conferences. Dr Bieber has a crucial role to play in this conference which will become apparent later.

Kalgoorlie Boulder is the major centre in the Goldfields region of WA. It was founded on gold alone, but today nickel and gold are its economic mainstays, with tourism, livestock production and service industries contributing to the local economy.

Our mean annual rainfall is some 250mm. Our mean annual evaporation from an open water surface is 2.4m! This is an arid area, but it has unique environments. The conference programme has been designed to allow you to experience a number of those different environments.

Following the structure of other Engineering Foundation conferences we will receive papers this morning and on Tuesday, Thursday and Friday mornings, and on Monday evening, and late on Tuesday afternoon. On Monday and Thursday afternoons, and all day on Wednesday we will take field tours. On Tuesday afternoon we will receive and view poster papers.

Turning now to international relations. The Cold War is over. Today's international relations are largely based on trade. The next large initiative that I can see will be to develop stronger international relations based on collaboration to overcome the environmental problems of arid areas. Without this the human species and a lot of other species may not survive in the long term.

I quote Iwao Kobari-san from his opening address to Desert Tech III :
"...we have a great responsibility in the future for Deserts, Development and Peace through sincere cooperation in the field of Desert Studies."

That is why conferences like this are so important.

On Thursday evening we will hold workshops and make proposals for the most urgent needs for research in arid lands. The proposals put forward at each workshop will be presented to the whole conference in the second half of Friday morning for endorsement as conference resolutions.

In conclusion I again welcome you to this fourth Desert Technology Conference - "Desert Technology for a Sustainable World"

Nearly all that the organisers or I can do is done. It is now your conference. You will shape it by your presentations and discussions.

I declare the conference open.

The World's Arid Areas - Global and Regional Assessment of the Past, Present and Future

Keynote Address

沙漠研究 7S, 1-13 (1998)
Journal of Arid Land Studies

The World's Drylands and Global Change in The Twenty-First Century: Challenges and Prospects

Victor R SQUIRES*

Abstract - Modern society has brought about massive changes in the world's physical environment -- changes which affect all life on earth. Our civilisation, through technological developments and burgeoning populations, has caused deforestation, desertification and the pollution of water and air. The global environment is now unstable. Major impacts are being felt already in the world's drylands -- that arid part of the earth that occupies 43% of the land surface and which is home to over 1 billion inhabitants. This is cause for concern and several International conventions have been put in place to respond to the crises. For example, the UN Convention on Desertification and Drought (CCD), the International Convention on Biodiversity and the International Convention on Climate Change. All three conventions are trying to focus on just one aspect of what is quite a complex set of problems. A key feature is that the various facets of the global crisis are inextricably linked through the global carbon cycle in quite complex ways. It has been said that "ecosystem management is not simply more complex than we think, it is more complex than we can think". The challenge for scientists and administrators is to devise strategies which can address these problems in a sensible way. An optimistic view is that technology can spare the earth. Evolving efficiencies in our use of resources suggests that technology can restore the environment even as population grows. Combating dryland desertification and global climate change through increased carbon sequestration in drylands is one option that has been explored. The prospects are that more than 1 gigaton (Gt) can be sequestered annually in the world's drylands. This would help slow the rate of global warming and contribute to the rehabilitation of drylands. This paper will explore a few of these issues, enumerate the drivers of change and speculate on how humans might cope with the manifestations of global change.

Key words: technology, population, economic growth, carbon sequestration

I. Introduction

Change is the key word in today's world. Global change will affect us all. Populations are rising, the climate is changing, economic systems are altering, communication nets are expanding. People are more mobile than ever before. At the dawn of the twenty-first century the whole world is undergoing a metamorphosis. The way we approach the world's deserts is changing too. New technologies, and new-found riches (minerals, biological resources or fossil water) are focusing our eyes on the desert regions of the world.

Traditional range/livestock systems on the world's arid and semi arid drylands are becoming extinct while new systems are

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beginning to emerge. The wonders of technology such as satellite imagery and other space-borne sensors have unlocked the secrets of the deserts. Concerns about global warming and other manifestations of climate change have seen a rising level of interest in desert regions as potential sinks for carbon dioxide and other greenhouse gases (UNEP, 1985; Squires, Glenn and Ayoub 1997). New ways to use saline water for irrigation, when combined with salt tolerant plants, have pointed to the value of coastal deserts as places to grow forage crops, food crops and even oil seed crops (Miyamoto, Glenn and Singh,1994).

In this paper I will provide a brief overview of the sort of changes which are happening the world over, and elaborate a little on the socio-economic and environmental changes which impact on people in the world's drylands. The role of drylands in mitigating global climate change will receive special attention.

2. Will the Future Work?

2.1. Drivers of change

"The future ain't what it used to be" (Groucho Marx)

The world is changing rapidly. For example, it took from the dawn of history to the beginning of this century for the world economy to grow to $600 billion. Now it increases by more than that every two years (Dowdeswell, 1996). There are three basic drivers.

2.1.1. Population growth, although slowing, is still rising (Figure 1) and the highest rates are in those countries which are least able to sustain them (Figure 2). Further analysis of the population growth pattern shows that three categories of nations exist (Figure 3). In the first group, population growth is below replacement (parts of Europe), in others at replacement fertility (eg. North America) and in some it is above replacement level (Asia, Africa, South America). This means that populations in some countries will double in less than 25 years, especially as life expectancy at birth is on the increase (Table 1). The subject of population growth is complex and controversial and must be approached with respect for various religious and ethical values and cultural backgrounds.

Figure 1 Projected world population growth to the year 2150 (UN median projection). Source: WRI (1996)

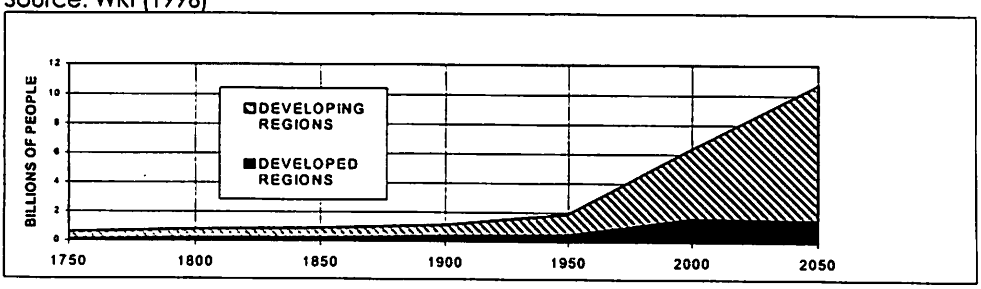


Figure 2 World population growth to the year 2150 as a function of fertility. Some regions will have populations that double in less than 25 years. Source: WRI (1996).

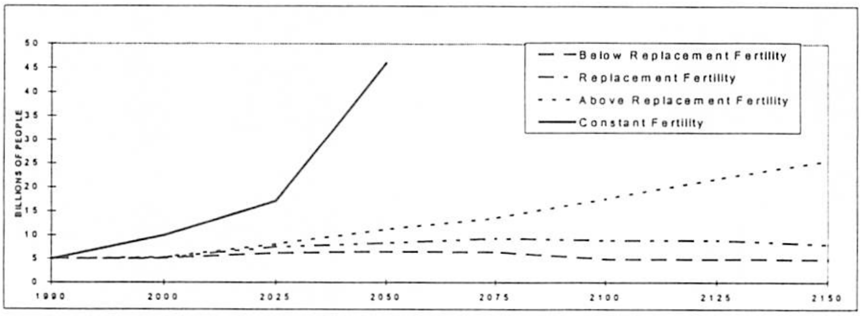


Figure 3 Population and poverty are closely linked. Often the poorest countries have the highest rates of population growth. Source: Data from Jazairy, Alamigir and Pannuchio (1992)

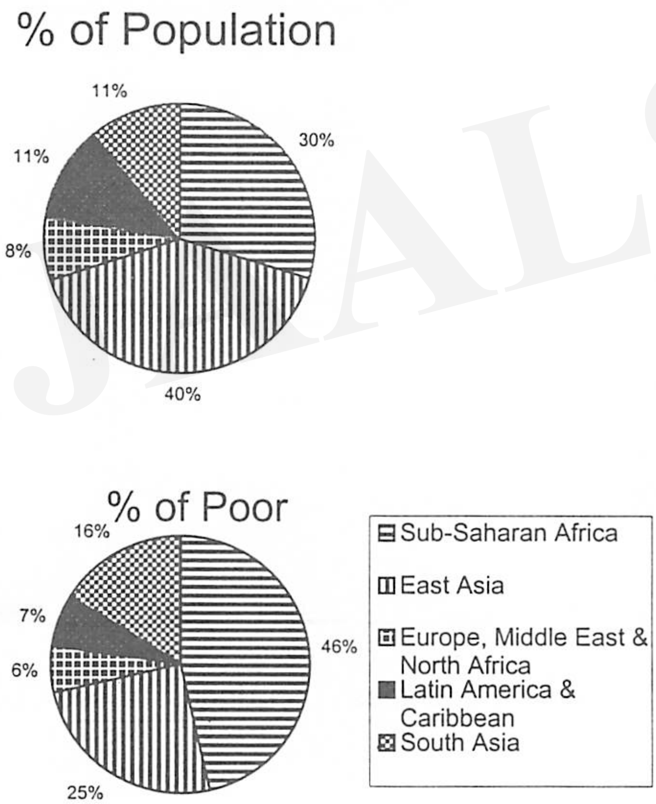


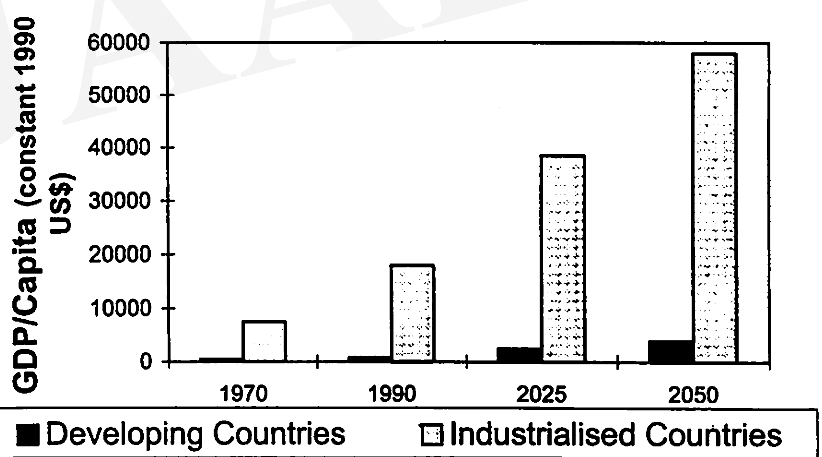
Table 1 Life expectancies for selected regions projected to 2050

Period	**Africa**	**Latin America**	**Asia**	**World**
1990-95	53.0	68.5	64.5	64.4
2000-05	55.8	71.0	67.9	67.1
2010-15	60.5	73.2	70.8	69.9
2020-25	65.4	75.1	73.2	72.5
2030-35	69.4	76.6	75.0	74.6
2045-50	73.4	78.6	77.4	77.1

Based on UN projections

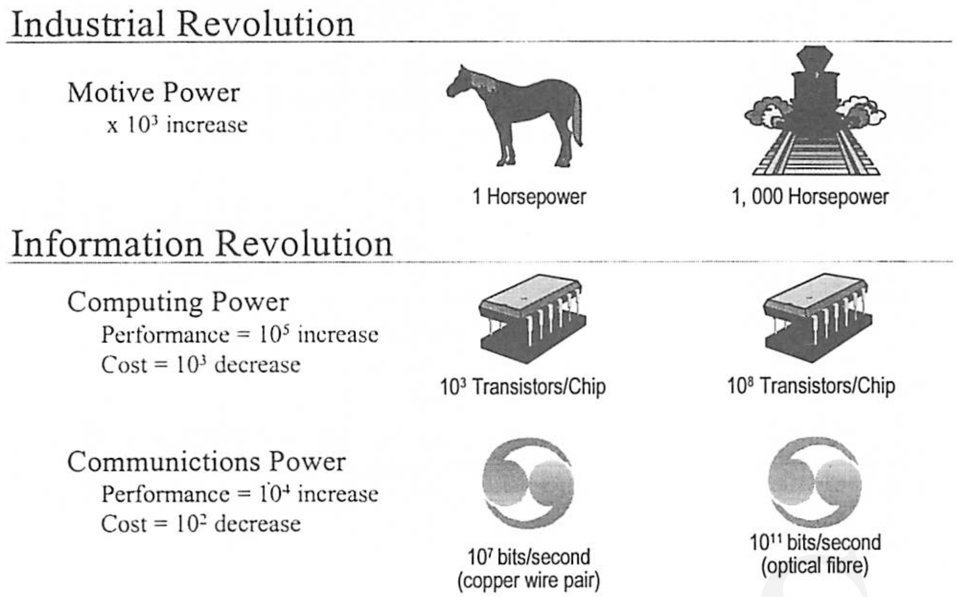
2.1.2. Economic growth is another major driver. Industrial production has already grown 50-fold during the 20th century and the World Bank (Serageldin and Steer, 1994) estimates that it could well increase by another 350 per cent by the year 2030. If present production trends and population growth continue, the Earth's carrying capacity will be exceeded before long (Dowdeswell, 1966). The disparity in income between the developed and the developing nations will get wider (Figure 4).

Figure 4 The projected income levels in developed and developing countries to the year 2050 show a widening gap between the rich and poor.
Source: WRI (1966).



2.1.3. Technological innovation is another major driver. The pace of change defies belief. Just consider the changes in the past century or so. The Industrial Revolution, important though it was, has been overshadowed by the Information Revolution (Figure 5).

Figure 5 Technological innovation and its impact on society.



2.2. Social factors affecting the future.

Trends are occurring which will have profound affects on society and in turn on the struggle to achieve sustainable development. Sustainable development is defined by WCED (1987) as "development to meet the needs of the present, without compromising the ability of future generations to meet their own needs". Sustainable development assumes the alignment of development decisions with environmental considerations (see section 2.4). One of the most fundamental problems confronting humans at present is how to meet the basic needs and goals of all peoples on Earth without simultaneously destroying the resource base, i.e. the "environment" from which ultimately these needs must be met (Young and Solbrig, 1993).

2.2.1. Urbanisation is a major factor, especially in less developed countries and newly industrialised countries. By the year 2000 almost half the world's population will live in urban areas and while urban population growth in developing countries as a whole has been slowing, a further three-quarters of a billion people will have been added to urban areas by the turn of the century. This shift is in response to changing methods in agriculture and to a large extent to the fact that the demographic profile has shifted. Yet is imperative that agriculture be modernised if there is to be food security. The change from subsistence agriculture to a full market economy is inevitable but it begs the question "will there be enough jobs?" (Jazairy, Alamgir and Panuccio,1992)

2.2.2 .Human investment patterns, family structure and education are also changing globally. Families are getting smaller as the burdens of dependents on working age parents increases. Women are assuming greater economic responsibility of families and there is a reduction in the quantity of resources invested in the next generation.

2.2.3. Social stability, violence and disorder. There are doubts about the stability of cities because of the rapid population increases, slow pace of infrastructure development and provision of services such as health, education and welfare There are many teenagers, they are restless and mobile. Regrettably, the job market is saturated and this leads to restlessness, violence and lawlessness. Because many are unskilled they are "stranded" in a technological society that has few uses for manual labour at the levels which present themselves.

2.2.4. Equity patterns are also a cause for continuing concern. The gap between the bottom one-fifth and the top one-fifth is widening. Equity considerations loom large. Inter-generational equity is also a factor. Bearing in mind the definition of sustainable development as including the provision for future generations. We could be like Groucho Marx and say " Why should I care about future generations – what have they ever done for me?" or instead take into account what might be the fate of our children's children. We should act in way that ensures that they all have opportunities to be at least as well off as we are (Young 1993).

2. 3. Environmental factors affecting the future

2.3.1. Resource depletion Everything that we need, want, use, abuse or consume comes from nature. Will it last? Ironically enough, the debate about resource depletion has shifted from concerns about non-renewable resources such as fossil fuels and minerals to fears that we will run out of renewable resources. There is a growing scarcity of renewable resources such as fresh water, food and fibre, forest products, fish and shellfish (World Resources Institute, 1996). As populations rise we will need more of these resources. In some regions there is a profound shortage of water (Figure 6a) and of arable land (Figure 7a and b).

Figure 6. Water is one of the renewable resources under threat. In some countries it will become a crisis early in the twenty-first century. Source: Data from FAO (1996)

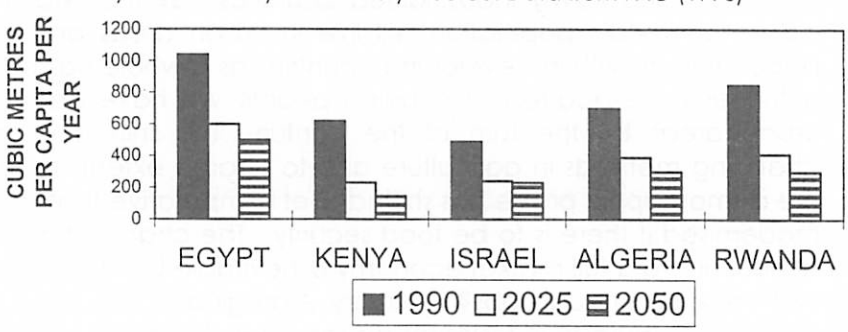
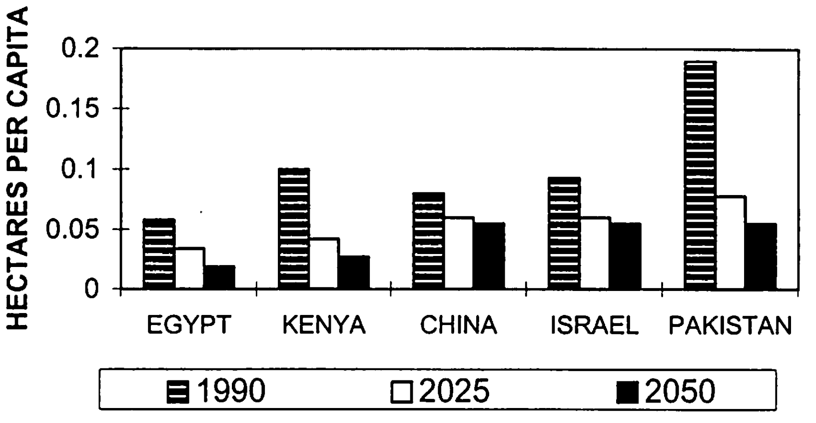


Figure 7. Cropland will become a limiting factor in some regions early in the twenty-first century. Source; Data from FAO (1996)



The rush to develop the world has damaged the natural systems that sustain renewable resources (Tolba 1982).

Examples of this are seen in:

- land degradation and soil loss
- spread of salinized wastelands
- build-up of pollutants in the air, water and soil
- damage to watersheds
- loss of biodiversity

Sustainable use places the focus on two groups of disenfranchised people: the poor of today and the generations of tomorrow. The rapid degradation of the natural resource base of the rural poor is significantly worsening their poverty (Jazairy, Alamgir and Panuccio, 1992). Many of the threats to the environment in the developing world occur as a result of poverty. Indeed, rural poverty and degradation of the environment are mutually reinforcing. When people's survival is at stake they are forced to overstock fragile grazing lands, cut trees for firewood and overuse ground waters.

Few aspects of development have been found to be so complex as the need to reconcile anti-poverty and pro-environment goals. The policy linkages and choices to be made have yet to be articulated. One pivotal point is that no long-term strategy of poverty alleviation can succeed in the face of environmental forces that promote persistent erosion of the natural resources upon which we all depend.

The economic, social and political conditions have changed so dramatically and profoundly over the past 20 years (Rasmussen,1995). The changes are so far-reaching. The following questions have been raised:

- Is pastoralism still a viable option?

- Are there alternative uses for the land?
- What are the biodiversity implications of a change in land use?
- How do we measure and monitor change?
- What are cost-effective techniques and tools to do this monitoring?
- How do we get involvement and participation by local people?

The ultimate question must be "Is pastoralism justifiable in the light of concerns about sustainable use of rangelands?" The papers presented elsewhere in this journal address some of these issues in more depth but it seems worthwhile to make the point that world wide there are upwards of half a billion people reliant on some form of subsistence livestock raising from desert and near-desert areas.

<u>3. Economic Growth, Carrying Capacity and the Environment</u>

The general proposition that economic growth is good for the environment has been justified by the claim that there exists an empirical relation between per capita income and some measures of environmental quality (Arrow et al, 1995). This statement though does not pertain to the environmental resource basis of material well-being (Preston, 1995). Economic activities are sustainable only if the life support systems on which they depend are resilient. The environmental resource base, upon which all economic activity ultimately depends, includes the ecological systems that produce a wide variety of services. This resource base is finite. There are limits to the carrying capacity of the planet but carrying capacities in nature are not fixed, static or simple relations. They are contingent on technology, preferences and the structure of production and consumption.

An optimistic view is that technology can spare the earth. Evolving efficiencies in our use of resources suggests that technology can restore the environment even as population grows (Ausubel,1996). The catch is that technology spares resources but also expands our niche. Technology further adds to population by increasing longevity and decreasing mortality (Table 1).

<u>4. New Uses for Old Lands</u>

<u>4.1. The technological fix</u>. Technologies have enabled us to expand our geographic range and transform the earth. New technologies are being applied to the desert regions of the world. For example, solar refrigeration and air conditioning, solar-powered saltwater desalinisation and the use of sensitive new detectors to find minerals and groundwater.

Golany (1983) in the book "Design for Arid Regions" outlined some of the ways in which humans can now transform desert regions into comfortable places for human habitation. There have been many innovations since then including some which enable humans, sometimes precariously, to hold on in the drylands of this world. The impact of new technologies on the oil-rich Gulf states is quite well known and the population shift to the southwest of USA into regions formerly regarded as to hot and uncomforable is quite extrordinary. The advent of air conditioning (houses, offices, cars) and the provision of water via canals has been the catylist.

The dramatic impact of some great technological leap towards the reclamation of deserts and arid lands has never lost its appeal. For example, the once-prominently considered plan to flood the Qattara Depression, some 100 m below seas level in the Libyan Desert, with water from the Mediterranean Sea. Benefits cited included: flow in the canal would provide hydroelectric power, the new lake would pour water into the atmosphere, and the vast underlying aquifer would be protected by a water "cap" on its principal natrural discharge (if the seepage of salinity did not prove to be too much of problem). The trouble with such a grand scheme, of course, is that, even when feasible, every fix, technological or otherwise, has its price. And what we have begun to learn, especially in recent decades, is that, unless the side-effects (negative externalities) can be foreseen with some precision, the risk of major environmental alterations may outweigh any benefits such schemes might offer. Constraints of energy, of water and soil salinity, of receding aquifers, of disturbed ecological systems, and of the habits and customs of the local people invariably, today, speak in the name of constraint.

4.2. Drylands as a sink for carbon dioxide: an agenda for the twenty-first century. But not all desert-development schemes are so intrusive and technology- driven. Deserts and near desert regions have a new, and potentially important, role to play in mitigating the rate of global climate change (EPRI,1994). The mechanism for this is through sequestering carbon dioxide and methane from the atmosphere.

Carbon sequestration, the process of carbon stock protection and aggradation, is being looked at as a viable option by a world increasingly worried about the potential impact of greenhouse gases and the concomitant global warming.

Arid lands may seem an unlikely candidate to be pressed into seruice for this purpose but their vast area (considerably greater than world's forested regions) means that even modest rates of sequestration can make a major contribution. The world's drylands store about 241 Gigaton (1 Gt=10^{15} tons) of organic carbon, 60 times more than is added to the atmosphere annually through fossil fuel burning. Small unit area changes in the rate at which carbon is emitted or sequestered in these soils can have relatively large impacts on the atmospheric carbon budget given the large area of the drylands.

It has been estimated that 1 Gt, or 15-20% of total CO_2 emissions, can be sequestered by drylands each year at a cost of betwen $10-18/t of carbon (Squires, Glenn and Ayoub, 1997). This is a significant contribution at lower cost than forest-based sequestration. And is in addition to the carbon sequestered by tropical rainforests and temperate forests. It is also a mechanism to transfer money from the rich north to the poor south. The mechanism is through a program of biotic carbon offsets (Trexler and Meganck, 1993). Put simply, an offset is any measure taken beyond the stack to mitigate the effect of the carbon emission. Sequestration by soils and vegetation in the world's drylands is one such measure.

It may be necessary to provide incentive payments to land users in the drylands to encourage them to manage the land in a way that maximises biomass and carbon sequestration. The compensation payments would more than cover the income foregone from reducing stocking rates or adopting other biomass-conserving management practices. Private corporations, principally coal-fired power stations and steel mills, who might otherwise incur carbon taxes can gain relief if they are able to demonstrate that the carbon dioxide emissions are sequestered for a long time period (Trexler and Meganck, 1993; EPRI, 1996) A fuller explanation of this intriguing possibility is to be found in Glenn et al, (1993), Squires, Glenn and Ayoub, (1997) and Squires (in press).

Another role for the drylands in reducing greenhouse gases is via methane oxidation. Methane, which is 24 times as aggressive in causing global climate change as CO_2, can be oxidized by desert soils. All well-aerated undisturbed soils, not subject to nitrogen fertilization, oxidise methane at a low rate, including very dry desert soils. The technical feasibility of the idea rests on the fact that there are 1 billion ha (globally) of hyperarid lands. Methane uptake is in the range of 1-30 kg/ha/yr (equivalent to 5-150 kgC/ha/yr). It can occur indefinitely. The right conditions for methane oxidation also obtain in much of the 5.2 billion ha of drylands which lie outside the hyperarid regions. The process is passive and benign. A major factor is that there are no social, political or economic risks and that it happens anyway. There are no operational costs.

4.2 Carbon storage in vegetation and soils in the drylands. There has been a reduction in the amount of carbon stored over the period 1850 to 1990; proportionately less is stored now in vegetation (Figure 8) because of land use change (Houghton,1994). Projected carbon storage in drylands for two scenarios are presented in Figure 9. The "business as usual" scenario is likely to lead to a situation where dryland soils act a net source of carbon whilst a scenario where dryland rehabilitation measures (as recommended by UNEP, 1991) are implemented would lead to a net carbon sequestration of 1.3 Gt/yr by 2020. Implementing the rehabilitation measures that change the drylands from a source to sink for carbon is a major challenge for scientists, policy-makers and administrators but obviously would have great social, economic and environmental benefits (Squires, Glenn and Ayoub, 1977).

Figure 8 Changes in carbon storage in vegetation and soil between 1850 and 1990. Less is stored in vegetation now as a result of land clearance and other land-use change.

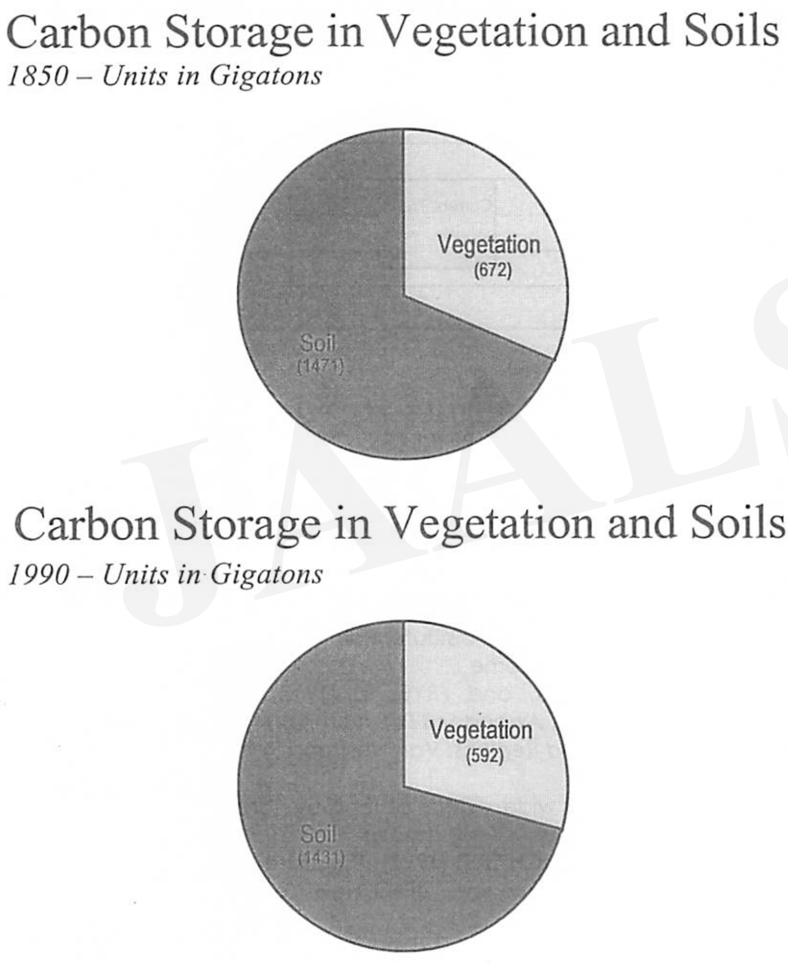
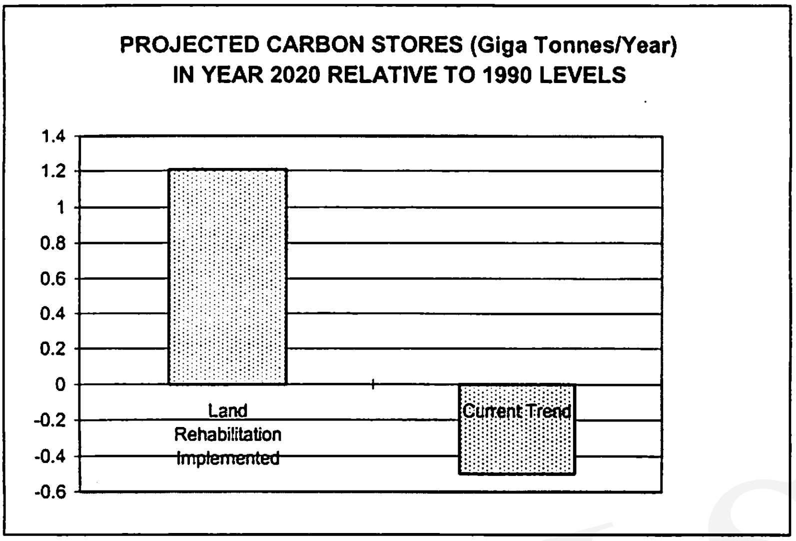


Figure 9 Projected carbon stores in the world's drylands by the year 2020 under two scenarios. If the UNEP-recommended measures to rehabilitate degraded drylands were adopted an annual sequestration of more than 1 gigatonne (10^{15} t)could be expected.



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The World's Arid Areas - Global and Regional Assessment of the Past, Present and Future

Session Papers

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Lithic Resource Depletion by Early Prehistoric Populations in the Desert West of North America

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Abstract - Archaeological studies carried out by the Desert Research Institute on the Nevada Test Site in the southern Great Basin of North America support the idea that specific locally available lithic resources were depleted significantly by prehistoric human populations. Hydration bands of 104 pieces of obsidian debitage from three expansive archaeological sites near Yucca Mountain are represented by measurements in the 8-13 micron range---values consistent with measurements obtained from Early Archaic points made from local obsidian sources. It is hypothesized that early exhaustive use of large obsidian and agatized chalcedony nodules significantly depleted these resources in the region.

Keywords: Lithic resources, depletion, recycling, obsidian hydration

1. Introduction

Yucca Mountain occurs on the Nevada Test Site in the southern Great Basin of the western United States, and has been the focus of investigations to determine its suitability for placement of the nation's high-level nuclear waste repository. Intensive archaeological studies associated with this process have been conducted by the Desert Research Institute over the past two decades (DOE, 1990). The region is generally quite arid, and typically receives between 100 and 200 millimetres of precipitation annually which is of low to moderate intensity with minimal runoff.

During the 10,000 or more years of human use of the Yucca Mountain region, it is likely that critical fluctuations occurred in the abundance and distribution of subsistence resources (e.g., water, plants, animals, lithic resources). These changes are expected to have had a significant impact on the ways in which the archaeological landscape manifests itself. Significant changes in settlement patterning, and therefore, changes in the nature, abundance, and distribution of artifacts in the region would have resulted from these changes (DOE, 1990:3-13). Because the great majority of sites so far known in the Yucca Mountain region are chiefly surficial in nature, they have little potential for providing information on plant and animal resources that may have been exploited through time. Sites in the Yucca Mountain area, where several different types of lithic raw materials are immediately available, are best suited, then, for addressing questions concerning lithic resources. This paper will focus primarily on the use of locally available obsidian.

Previous studies of obsidian quarries on the Nevada Test Site (Amick et al., 1991; Reno et al., 1989) show significant use of this material by early populations, and evidence of intense recycling, particularly by late-Holocene populations. Several lines of evidence from these and other sites in the region support the idea that locally available lithic raw materials, especially obsidian, may have been depleted significantly by terminal-Pleistocene/early-Holocene human populations. Because obsidian develops a measurable weathering rind through time, it is uniquely suited to answer questions of use through time at sites that do not have datable stratigraphic contexts.

2. Evidence of lithic resources depletion from obsidian hydration studies

In the Yucca Mountain area, obsidian occurs as secondary deposits of small nodules along the alluvial terraces of Topopah, Fortymile, and Yucca Washes. Primary occurrences of obsidian with this trace element signature are unknown, and may no longer exist. Obsidian hydration measurements from

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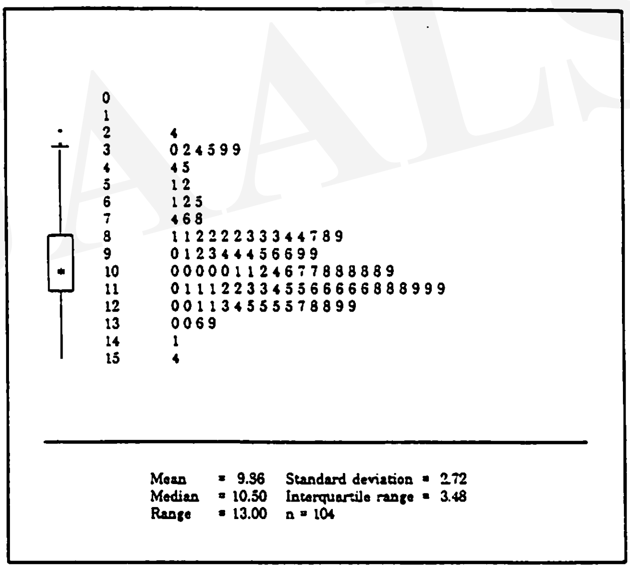
three extensive archaeological sites in the area (26NY1011, 26NY4759, and 26NY7920) located along deeply entrenched ephemeral washes were examined to see if any regional trends with regard to obsidian use could be recognized (Hartwell et al., 1996). All three sites are primarily surficial in nature, and each contains an early component of projectile points representing an Early Archaic adaptation known as the Western Stemmed Tradition (Beck and Jones, 1990; Bryan, 1980; Willig and Aikens, 1989), although diagnostic projectiles spanning the entire range of human occupation into historic times are present.

The sites all show evidence of on-site reduction of obsidian in the form of split cobbles (cf. Amick et al., 1991:37-39; Reno et al., 1989:81) and interior flakes. Hydration band measurements were obtained from a sample of obsidian debitage from the three sites as part of a continuing program of obsidian studies near Yucca Mountain (Rhode, 1992; 1994; 1997). Thirty-six pieces from site 1011 were measured, 42 pieces from 4759, and 26 pieces from 7920. All of the data profiles show significant early use of obsidian, followed by a steady decline and then sudden drop-off, a trend which is especially noticeable when data from the three sites are combined (Fig. 1). Intuitively, it is expected that early use at the three sites should display similar profiles for that time period. However, measurements at the early end of the profile for 7920 are 1-2 microns thicker, in general, than at the other two sites. These differences may simply be related to microenvironmental differences between the sites which have influenced hydration rates, although somewhat earlier occupation of this site must be considered.

Figure 1. Obsidian Debitage Hydration Data from Sites 26NY1011, 26NY4759, and 26NY7920.



Eighty-four percent of the debitage is represented by band measurements falling within the 8-13 micron range. Hydration rates for the local Fortymile Wash obsidian source (8.56-8.99 μ^2/1000 years), derived from measured density of internal water content (Ambrose and Stevenson, in press), suggest that hydration values greater than 8 microns are in excess of 7,500 years in age. These values are consistent with measurements obtained from Western Stemmed Tradition and Pinto points made from local obsidian sources, and are indicative of the earliest intensive occupation in the region. The data suggest a significant drop-off in production of obsidian debitage after 8 microns at these sites.

3. Further evidence for lithic resource depletion

The above data suggest that early exhaustive use of large obsidian nodules significantly depleted this resource in the Yucca Mountain region, so that large nodules were not readily available to later populations (Hartwell et al., 1996). The obsidian hydration data are not in themselves a strong indication that this resource was being depleted, since other factors (e.g., occupational intensity) may have contributed to the results obtained from this study (e.g., Haynes and Buck, 1995). However, the presence of large cortical flakes at the sites indicates that obsidian nodules with diameters greater than 7 cm once existed within the local alluvium. Nodules of this size are now scarce in the lowlands of the Nevada Test Site. In fact, it is difficult to find nodules greater than 2-3 cm in diameter. The presence of debitage at the sites that is larger than the nodules that remain indicates that this resource has been significantly depleted. Sites such as 1011 and 4759, at which other lesser-quality lithic materials (welded tuff and agatized chalcedony) also occurred, probably experienced more intensive exploitation of these resources as large obsidian nodules were exhausted. Indeed, at site 4759 there appears to have been significant depletion of agatized chalcedony nodules as well (Buck et al., 1994). Reconstructed lithic cores of this material are significantly larger than unmodified cobbles that still occur on-site.

Additionally, examination of raw material usage for projectile point (Buck et al., 1994:119, Table 5.1) shows an increasing reliance on non-obsidian resources for production of projectile points through time. Almost 89% of all Early Archaic diagnostic points (n=192) are made from obsidian (with more than 73% of these points being made from locally available obsidian) while later prehistoric point styles display a steadily decreasing proportion of obsidian use through time. There is an increase in the proportion of the latest prehistoric points manufactured from obsidian. However, this may be a result of the generally small size of this arrow point type, which would permit exploitation of the small nodules still extant in the alluvium. This may also explain the late "spike" in the data of the obsidian hydration profiles at the sites just discussed (Fig. 1). It is inferred that this trend toward use of lithic materials other than obsidian reflects an increasingly limited obsidian supply in the Yucca Mountain region, a trend that was probably enhanced by increasingly sedentary populations relying on more localized resources. It is unlikely that this shift is indicative of a change in material preference, since obsidian remains the dominant material for all point types from the Nevada Test Site through time.

4. Conclusions

Early Archaic point technology appears to have relied especially heavily on obsidian use in much of the Great Basin of the Western United States, regardless of the availability of other lithic resources (Amick, 1993; 1995). This practice likely contributed to significant depletion of this resource early in human prehistory in areas such as the Nevada Test Site, where primary sources of obsidian are unknown. Projectile points representing the earliest significant occupation of the Yucca Mountain region typically exhibit significant battering damage presumably incurred during attempts to recycle them. Amick notes that "battering impacts are generally weathered to the same degree as the rest of the artifact, suggesting that heavy blunting of the edges occurred within the use life of the tool" (Buck et al., 1994:69). Intensive recycling of exhausted obsidian tools, observed at sites such as Buckboard Mesa on the Nevada Test Site (Amick, 1990; Amick et al., 1991), is likely a direct result of depletion of this resource, and probably had other significant consequences for procurement strategies and land use patterns. Other possible consequences of lithic resource depletion include an increased emphasis on opportunistic exploitation and an alteration of settlement strategies incorporating visits to alternative lithic resources (cf. Buck et al., 1994:113; Haynes and Buck, 1995).

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Arid North Coast of Peru: Survival Strategies of Ancient Civilizations

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The coast of Peru is one of the arid regions of the world where ancient civilizations flourished. The Moche Valley on the North Coast has been continually occupied since 11,000 B.C. with urban societies developing about 1,000 B.C., utilizing strategies to contend with the lack of terrestrial food. Yet environmental events, such as the El Nino, heavily impacted their societal organization. An examination of the archaeological records shows the effects of these events on the people who lived there in ancient times and how their system continues today.

Key Words: Archaeology, Peru.

1. Introduction

The Andean mountain ranges run northwest to southeast across central and most of western Peru and encompass three cordilleras which reach heights more than 6,000 meters. On the eastern slopes of the Andes is the montana, the forest region, and at the lowest elevations, the tropical rain forest, best known as the Amazon Basin. On the western side of the Andes, where the mountains reach their greatest height, they abruptly descend to a narrow strip of desert along the Pacific Coast. This desert is created by a combination of factors. In the Pacific Ocean near the coast is an upwelling of cold water, called the Peru Current, which creates an abundance of marine life. However, the cold water also cools the air, reducing evaporation, and as the air moves over land the higher temperatures hinder rather than encourage rainfall. Since the westward moving air from the Atlantic Ocean sheds its moisture over the eastern Andes, the annual rainfall in the desert is less than one centimeter per year. However, infrequently, no more than three or four times a century, heavy rains occur as far south as the central coast of Peru. This phenomenon is referred to as El Nino, the Christ Child, because it has happened near the Christmas season. The mechanism which triggers El Nino involves a change in the temperature of the ocean current, the atmospheric conditions, and the trade winds, combining to produce rainfall which lasts several weeks and devastates an area adapted to a dry climate (Diaz and Markgraf 1992; Philander 1990). This rainfall upsets the marine ecosystem producing an absence of fish along the coast (Glantz 1996: 47-69).

In this arid coastal environment, civilizations flourished in spite of the scarcity of indigenous edible plant foods and water sources (Moseley 1974). Some of the greatest prehistoric urban centers were located on the North Coast of Peru in and near the Moche Valley (Bankes 1971;Larco Hoyle 1948; Moseley and Day 1982; Pozorski, S. 1978; Pozorski,T. 1978; Ravines 1970; Schaedel 1951). However, archaeologists traditionally have looked at this archaeology in terms of political power (Haas et al. 1987).

2. Ancient Moche Valley Cultures and their Adaptations

2.1 Chronology of Ancient Cultures Human occupation of the Moche Valley forms a continuum from 11,000 B.C. until today. The earliest sites consist of chipped stone artifacts in association with extinct megafauna (Ossa and Moseley 1971). Only a partial record of the earliest cultures exists because at the end of the Pleistocene the shoreline was at least fifty kilometers further west and was inundated as the level of the Pacific Ocean rose in the early Holocene (Richardson 1981).

The development of urban centers began in the Cotton Preceramic (2,000 B.C.) on the Central and North Coast of Peru (Moseley 1974). The sites are deeply stratified with

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formal and residential architecture, associated with twined, cotton items (Pozorski, S. 1978), the attributes of civilization without the domestication of food plants. These cultures were based on a marine economy which grew cotton within the banks of the river. In the Moche Valley, occupation at the Cotton Preceramic sites continued through the introduction of ceramics and into Cupisnique times (1,000 to 600 B.C.). At the beginning of this epoch, Caballo Muerto was built, a large Cupisnique site near the neck of the valley, consisting of eight, separate platform mounds with ornate mud friezes, spread over a two kilometer square area. (Pozorski, T. 1978).

Between 500 B.C. and A.D. 1000, a series of urban societies, called the Salinar, Gallinazo and Moche, successively occupied the valley. The primary Salinar site was built on ridge tops near the coast and contained more than 2,000 structures. The main Gallinazo site was up the neck of the valley with agglutinated masonry rooms covering the side of a canyon (Bawden 1977). Huacas del Sol and de la Luna, large adobe mounds, formed the administrative and religious center for the Moche Culture. They were built near the coast south of the Moche River (Richardson 1994: 102-106). The Moche dominated the valley for several hundred years with the move of the administrative center from the coast to the site of Galindo at the neck of the valley around A.D.700. Following the end of the Moche Culture, the Chimu Culture (A.D. 1250) emerged and built its rulers' palaces on a bluff overlooking the ocean (Keatinge 1974). The Chimu ruled the region until they were conquered by the Incas in the late 1400s, only decades before the arrival of the Spanish Conquistadores (Moseley and Day 1982).

2.2 Adaptive Strategies

The adaptive strategies of these prehistoric urban cultures had to balance food, water and political power in a desert valley, desolate except for its one river. While a maritime economy created urbanization, other adaptations accommodated an expanding population and, at times, expanding political territory. The cultural prehistory of this valley shows a trend of principal settlements rotating from coastal locations to inland locales through time, while satellite fishing settlements continued along the coastline. These small habitations provided the maritime resources needed by the valley's inhabitants.

S.Pozorski (1983) identified this trend in the early cultures, prior to 500 B.C. The author's analysis of the road networks and their relationships to large urban centers, small communities, and irrigation systems, documented that this shift continued through prehistoric times into historic times (Beck 1992). Challenging the archaeological model that political centers move due to cultural change, the reconstruction which follows is an environmental view of the archaeological data with acknowledgment that power and politics also had their role in prehistory.

The relocation of the ancient cultures' primary settlements from inland to coast, again and again through time, reflects their dependence on marine life, the Moche River for irrigating crops, and people's response to heavy rains and flooding. Ironically, as the Pacific Ocean provided the marine resources to develop urban society, these resources had to be procured away from the location where the river ran into the sea because the fresh water was not compatible with the salt water life. Hence, the Cotton Preceramic sites (2,000 B.C.) were located away from the river, overlooking the ocean, with fresh water being carried to the inhabitants. In Cupisnique times (1,000 to 500 B.C.), inland sites away from the ocean and near the river became important because they were more easily defended due to adjacent mountains and probably were thought to be more protected from the El Nino floods. Also, at this time, labor groups built small canals from the Moche River to agricultural plots and constructed road systems which facilitated commerce and guided people through the deserts and into the mountains (Beck 1992). These rapid cultural changes and achievements set the course for the success of humans in the region.

Following Cupisnique times, the Salinar (400 B.C.) built their main site very near the ocean but on top of a mountain. The site is not defensive. Instead its location is high above the flood and its placement must be a result of El Nino rains. Eventually, people returned to an inland location during Gallinazo times (200 B.C.), to a location where they could control the water in the river, but were several kilometers inland from the flood plain. Then, the Moche built their political center near the ocean along the river and constructed canals down the south side of the valley to their habitation location (A.D.300). The site also was positioned along the only coastal travel route and controlled the movement of people through the area. The Moche had easy access to marine resources, agricultural resources and fresh water, all contributing to their successful dominance of this and adjacent valleys. Archaeological evidence shows that an El Nino with its rains affected this area around A.D. 700 and may have caused the political downfall of this administrative center. Abruptly the people left the main site and began living in a different type of settlement, called Galindo, near the valley neck (A.D.700-1000). This site was not a political center and had fewer inhabitants. It is difficult to imagine the havoc that continual rains would create on a pre-industrial society, using adobe as its main construction tool. The archaeology shows that roads and canals were swept away and had to be rebuilt. Such devastation would undermine political and religious power and it probably was easier to move away and start again than to try and rebuild the damaged settlements.

The Chimu political center, called Chan Chan, is different from its predecessors. This was the first administrative center to be built in the northwestern end of the Moche Valley. Beginning around A.D. 1250, palaces which functioned as the rulers' homes and as administrative centers were built at the west end of the irrigation systems, far north of the Moche River. Fresh water came from these canals and walk-in wells. Reservoirs flanked the palaces and were used to grow totoro reeds for boats. Elaborate walled roads controlled all entry and exit from Chan Chan and through the valley. However the palaces were surrounded by six meter high adobe walls with only one entrance into the compound (Moseley 1992: 248-252). While the usual explanation is defense and privacy, the walls probably were built to protect the interior of the palaces during the El Nino floods. The Chimu controlled this valley and the regions north and south for several hundred kilometers. Therefore, defense seems unlikely and privacy was guaranteed by the isolated location. Chan Chan was built on a bluff overlooking the Pacific Ocean and, although, it was not in a major drainage, it would have been subjected to running water as the drainages overflowed. These walls probably helped considerably because a large El Nino did occur toward the end of the Chimu reign. The Chimu had extended their canal system to its maximum in all regions of the valley and even built an enormous canal from the Chicama River to the north, south to the Moche Valley, to ensure a continual, maximum water supply. Flooding from the El Nino destroyed sections of this intervalley canal which were never rebuilt. However, the walls and the interior of the administrative center of Chan Chan remained intact. After the Incas subjugated the Chimu (late 1400s), they dispersed the Chimu people to various parts of the Inca Empire and the Incas never built a settlement in the Moche Valley.

Since the Spanish conquest, habitation in the Moche Valley has been confined to two main areas, the city of Trujillo and the town of Huanchaco. The prehistoric pattern of moving settlement in response to climatic conditions has not occurred in the intervening four hundred years. However, the ancient irrigation systems continue in use today. Agricultural fields of sugar cane dominate the valley floor, but cover only sixty-five percent of the area which was under irrigation at the height of the Chimu Empire. The main town in the valley today, Trujillo, was built as a fortified Spanish town encircled by a wall which inadvertently helped protect against flooding. North of Trujillo is Huanchaco, a small fishing village on the beach below the bluff. This modern settlement pattern of a main city with a satellite coastal settlement is a repeat of ancient adaptations. Still, the El Nino can have devastating effects on modern life, washing away homes, roads, utilities and crops.

3. Conclusions

The successful adaptation of humans to the Moche Valley is a story of ingenuity, resilience and adaptability which continue into today. For thousands of years, management of fresh water, floods, and sea water resources has been integral to life in this desert valley. Ironically, the El Nino rains persist in their ability to devastate a desert whose occupants are in perpetual need of more fresh water resources.

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Monitoring Grazing Impact with Satellite Data

Gary BASTIN and Vanessa CHEWINGS[1]

Abstract - Large paddock size, complex vegetation patterns and variable rainfall make assessments of grazing impact difficult in Australia's rangelands. Methods that use satellite data to separate adverse grazing effects on vegetation cover from that caused by spatial and seasonal variability are illustrated. We show how the results arising from these analyses can be verified with airborne video data.

Key Words: Land degradation, Monitoring, Grazing gradient, Satellite data, Videography

1. Introduction

Knowing the effect that grazing is having on the soil and vegetation resource, and being able to adapt grazing management accordingly, is an important component of sustainably managing our rangelands. Assessment of grazing impact is made difficult because large paddocks contain a complex of land types which are grazed in a non uniform manner by sheep and cattle, and the vegetation present on each responds in often unpredictable ways to the infrequent rainfall that is received. Graziers thus face a difficult task in matching animal numbers to the available forage following erratic rainfall. They must also ensure that favoured grazing areas that carry most of the livestock for most of the time are not damaged by over-utilisation.

Land degradation caused by excessive levels of grazing can involve adverse changes in the species composition of pasture, loss of vegetation cover in some areas leading to accelerated erosion, and replacement of herbage species by unpalatable trees and woody shrubs in other areas. All processes result in a decline in grazing productivity.

Ground-based assessment of land degradation usually involves a trade-off between approximate methods, which give broad spatial coverage but are subjective and non-repeatable, and precise methods which only apply to very small areas and are not representative of diverse landscapes. Satellite data, which are available for whole regions and have frequent coverage, offer the opportunity of objective and repeatable information. However, satellite data require the use of surrogate indicators of land degradation. These are based largely on spatial patterns and temporal behaviour of vegetation cover (Pickup *et al.*, 1994).

2. Processing Satellite Data to Assess Land Degradation

The spectral contrast between bare soil and vegetation, or different levels of vegetation cover, in the visible-green and visible-red bands of multispectral satellite data (e.g. Landsat MSS and Landsat TM) is used to calculate the PD54 index of vegetation cover (Pickup *et al.*, 1993). This index, when compared with ground measures of cover, has provided reliable estimates of vegetation cover across different landscapes and through time (correlations in the range r=0.8-0.9). Having determined vegetation cover from the spectral properties of satellite data, the next requirement is to search for systematic spatial patterns in the data that are related to livestock grazing.

Free-ranging sheep and cattle in the large paddocks of the rangelands are dependent on sources of drinking water. This spatially predictable aspect of grazing behaviour is used to help separate natural change in the vegetation from that caused by land degradation. Vegetation cover typically decreases towards watering points to produce a "grazing gradient" (Pickup, 1989; lower solid line in Figure 1). Cover increases after significant rainfall and, where cover in the vicinity of watering points is fully restored to those levels present at some distance from water (upper line in Figure 1), grazing effects are temporary and no long term damage has occurred. However, where the gradient persists (dashed line in Figure 1), then some form of damage has occurred. We use this model to define land degradation as *a grazing-induced reduction in the amount of vegetation cover likely to be present after the best growth conditions experienced in a reasonable time* (Bastin *et al.*, 1993).

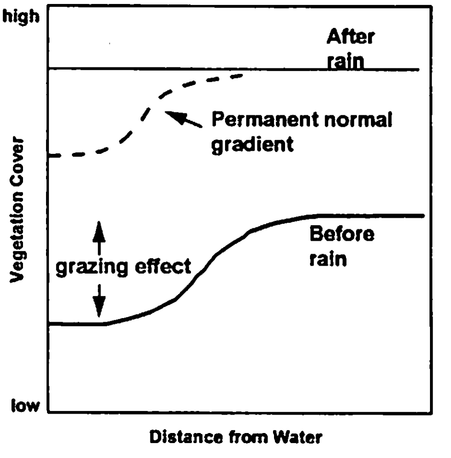

Fig. 1. A normal grazing gradient.

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3. <u>Grazing gradient analysis</u>

Grazing gradients are detected at the paddock scale by calculating average cover levels at increasing distance from watering points. This can be done by radiometrically standardising dry and wet period satellite data, calculating the PD54 index of vegetation cover and incorporating spatial information which controls grazing behaviour. Such information includes the locations of fences and natural barriers (e.g. mountains) which form paddocks, distance from watering points and the boundaries of vegetation communities which influence grazing preference. We call this form of grazing gradient analysis the *wet period average cover* (WPAC) method. A variant of this approach, the *resilience method*, is used to produce an image showing where vegetation response to rainfall is above or below that which might be expected given little or no grazing impact (Bastin *et al.*, 1996). Below-expected response often results from land degradation and can be indicative of low productivity in the long term. Above-expected response indicates a resilient landscape which may be in good condition, recovers well from defoliation by grazing and is likely to be productive.

4. <u>Application of grazing gradient technology</u>

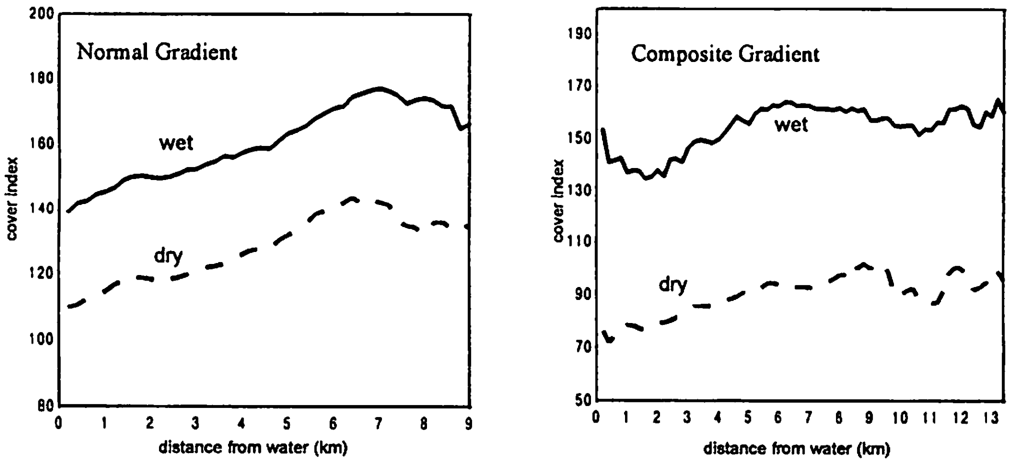
The first major application of the grazing gradient technology was to assess the extent of land degradation across 38,000 km^2 of central Australia using the wet period average cover method (Bastin *et al.*, 1993). Collaborative work was then conducted with a pastoralist family to trial the resilience method as a tool for property management planning (Bastin *et al.*, 1996). Both methods have now been adapted into a consolidated package for use by State land management agencies. The technology is currently being evaluated for the assessment of pastoral leases in northern South Australia by the Department of Environment and Natural Resources and on the Barkly Tableland of the Northern Territory by the Department of Lands, Planning and Environment.

<u>4.1 Wet period average cover method</u> In central Australia, three characteristic patterns of cover change with increasing distance from water were apparent from grazing gradient analyses made using the WPAC method. These were the <u>normal</u> gradient, the <u>composite</u> gradient and the <u>inverse</u> gradient and a typical example of each is shown in Figure 2. Normal gradients involve a progressive increase in average cover with distance from watering points. In some instances the gradient disappears after substantial rainfall indicating that the grazing effect is temporary. In the most degraded situations, the gradient often persists for between four and ten km from water. These persistent gradients are generally associated with the most preferred vegetation communities that have had an extended period of heavy grazing. Such areas are often intensively grazed to the point where all edible forage may be removed. Reduced cover results in increased runoff and erosion producing a less favourable soil environment and less moisture for pasture re-establishment following rain.

Landscapes with less erodible sandy soils tend to be less permanently affected by grazing. Soil disturbance by trampling adjacent to watering points may enhance rainfall infiltration while marginally increased soil fertility through the accumulation of livestock excreta can result in increased growth of unpalatable forbs following rain. This extra growth produces the composite wet-period gradient illustrated in Figure 2. Inverse gradients are generally associated with dams located in areas of predominantly woody vegetation. These areas receive additional runon water following good rains, are prone to shrub increase and have a greatly reduced supply of palatable forage. Cattle are forced to forage further from water producing the inverse dry-period gradient of Figure 2. Vegetation may fully recover across the entire area of this vegetation community following rain, or it may always remain higher in the vicinity of watering points. Landscapes with very little palatable forage such as spinifex sandplains or dense mulga shrublands are relatively unaffected by grazing and often have no discernible gradient in vegetation cover with distance from water.

<u>4.2 Resilience method</u> While WPAC is suitable for describing the state of a whole vegetation community, it provides no information on the location of areas with above- or below-average vegetation growth, apart from their distance from watering points. The resilience method can handle this problem of location-specific data. In keeping with local variability caused by moisture redistribution, soil differences, past grazing, etc., each location should have an expected response to rainfall (Pickup *et al.*, 1994) which represents behaviour in an ungrazed or sustainably-grazed situation. Observed response can be compared with expected response and areas which are below acceptable limits identified and mapped. The difference between observed and expected response then provides a measure of the resilience of the vegetation community to grazing.

Expected cover response is calculated as a linear regression between initial (dry-period) cover class and cover response following a major rainfall. Because cover response is partly dependent on the initial cover level (i.e. cover can increase only marginally where initial cover is high), residuals from the regression are scaled by the variance of cover response stratified with respect to initial cover. These residuals are then mapped as broad categories which show where vegetation response is above average, about average and below average (Figure 3).



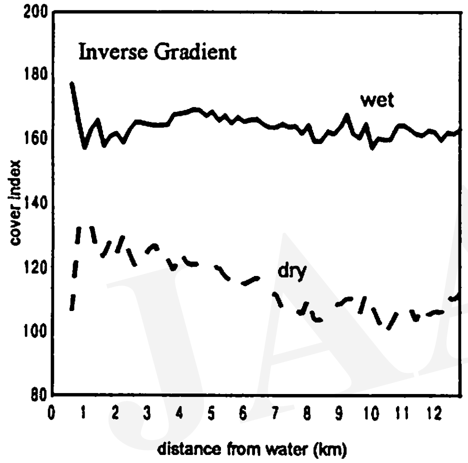


Fig. 2. Examples of typical dry- and wet-period grazing-gradient types obtained from the analysis of Landsat MSS data across 38,000 km^2 of arid rangeland grazed by cattle in central Australia. The cover index is the PD54 index of Pickup *et al.* (1993).

The resilience image for the example paddock shows that most of the area had an average to above-average vegetation response following the most recent large rainfall event. The largest area of above-average response was in a broad watercourse in the north-eastern part of the paddock where alluvial soils and runon water combined to produce ideal conditions for herbage growth. Pasture growth on much of the eastern side of the paddock was average to above-average because this area has loamy calcareous soils with good nutrient and infiltration qualities and is somewhat remote from stock water. Areas shaded light grey in the north-west of the paddock are mainly associated with poor vegetation response on eroded country. The elongated strip of below-average response mapped towards the south-eastern corner of the paddock is associated with a heavily shrubbed watercourse where high dry-period cover retarded the magnitude of vegetation response to rainfall.

By providing an overview of vegetation response, the resilience method can suggest options for improved paddock management and provide a means for monitoring rangeland trend. In this case, based partly on the availability of a resilience image, the lessee has piped water to the previously intermittently grazed eastern part of the paddock, undertaken extensive ripping of warrens to control rabbits and is building water retention banks to regenerate eroded country. A vegetation-response ratio can be calculated by comparing areas close to water (e.g. within 4 km) with benchmark areas further out. Systematic changes in this ratio over time can indicate trend or longterm change in land condition attributable to grazing (Pickup *et al.*, in press).

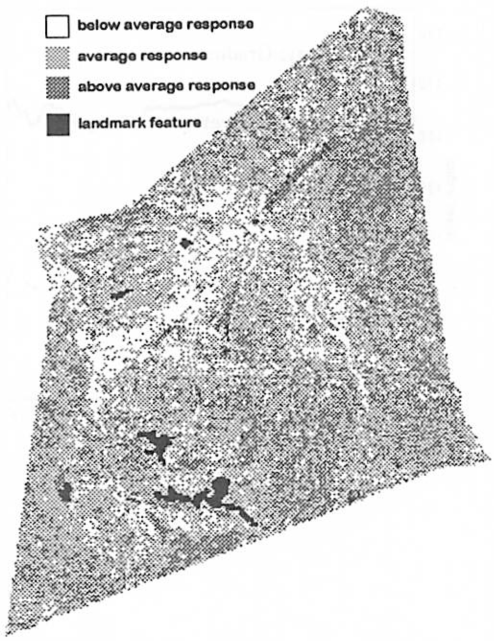


Fig. 2. Vegetation response for a 340 km^2 paddock following 350 mm of rainfall in March 1989

5. Verifying Analyses of Satellite Data Using Aerial Videography

Ground truthing of satellite data using conventional ground-based vegetation survey techniques is very difficult given the spatial complexity of the large areas commonly assessed. To reduce this problem, we have developed an airborne videography capability. This consists of four cameras, each fitted with a different filter in bands similar to the visible and near-infrared channels of the main remote-sensing satellites. Images are corrected to remove the effects of spatial distortion and differential illumination (Pickup *et al.*, 1995) and are then analysed using standard image processing techniques to produce estimates of vegetation cover.

By classifying the video data into spectrally distinct components, we have found close agreement between the video data and estimates of vegetation and soil components made on the ground (Pickup *et al.*, 1995). In video data at coarser pixel resolutions, obtained by flying higher, we have used the PD54 index to estimate vegetation cover. We have then been able to compare this measure of vegetation cover with that derived from contemporaneous Landsat TM data processed to produce the same (PD54) index of cover (Chewings *et al.*, 1997). Based on these encouraging results, we are confident that aerial videography can largely replace conventional ground-survey techniques in verifying satellite data. We are now routinely using the video system to acquire imagery at a range of pixel resolutions. These data are either classified or processed to the PD54 index to produce estimates of vegetation cover on what are often spatially complex landscapes. In this way, we are progressively verifying the results of our grazing gradient analyses made over extensive areas in central Australia.

Acknowledgments

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Satellite Monitoring of Bush Fires in Western Australia

Richard SMITH, Carolyn MCMILLAN, Ronald CRAIG, John ADAMS and Mike STEBER*

Abstract - Bushfires in Western Australia are routinely monitored from the NOAA-AVHRR satellite. Observations indicate year-round occurrence with upto 20 million ha each year (8% of the WA) being burnt. In the tropical savannas of the north west the burnt area increases to 30% of the land area. The NOAA-AVHRR satellite is used in near real-time to support bush fire management by monitoring: fuel load build up; curing to assess fuel flammability, hot spots to detect fires and total burnt area to create a fire history. The implications and use of this information for improved bush fire management in arid areas are discussed.

Key Words: Bush fires, NOAA-AVHRR, monitoring

1. Introduction

Wildfires fuelled by grassland growth occur globally (Robinson, 1991). Incidence of bush fires in the arid areas of Western Australia vary with the seasonality of the rainfall. Managing this variability presents a major challenge for achieving ecological sustainability and reducing greenhouse gas emissions (Beringer et al 1994). Lack of near real-time information on the spatial and temporal distribution of bush fires has inhibited the development of improved management practises. Therefore data from the National Oceanic and Atmospheric Administration's (NOAA) Advanced Very High Resolution Radiometer (AVHRR) satellite sensor are routinely processed by DOLA to provide near real-time management information on: *fuel load* build up following rainfall (Smith 1994), *curing* of vegetation during the dry season to estimate flammability (Paltridge and Mitchell, 1988), hot spots to locate *active bush fires* (Matson et al. 1987) and maps of recent *fire scars* to provide an *historical record* for understanding ecological effects and improving controlled burning practise.

2. Results

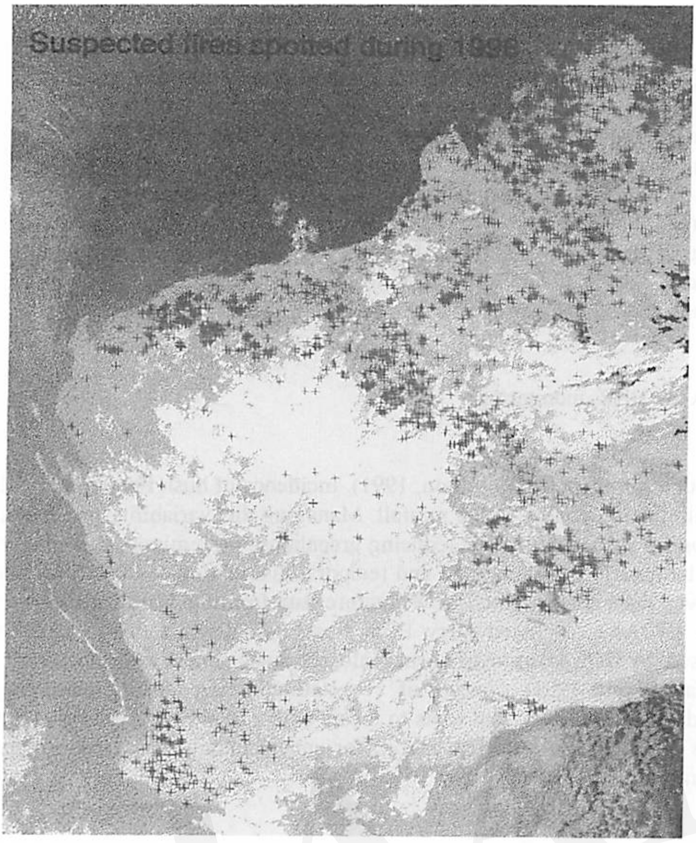
The magnitude of the fires to be managed is illustrated by the area burnt from 1993 to 1996 in the Kimberley area of north western Australia which varied from 2 to 15 million ha. (Table 1). The area often exceeds the 6.8 million ha size of Tasmania. Fires in the north begin at the onset of the dry season in April and reach a peak between August to November and cease with the onset of the wet season in December. The maps of fire history in the north west are used to analyse and improve the outcome of controlled burning strategies undertaken by the Bush Fires Board and CALM.

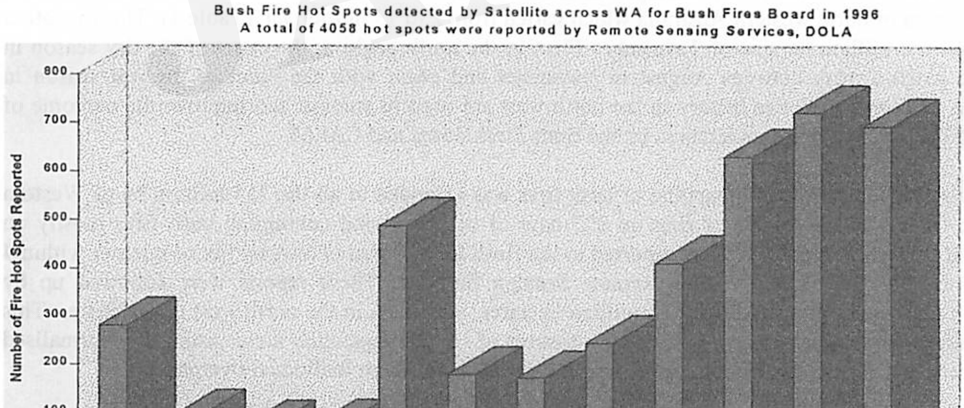
From April 1995 detection and mapping of bush fires was extended to all the 253 million ha of Western Australia. Over 4,000 hot spots of fires on 227 days of both new and continuing bush fires mostly on crown land were detected. They were reported to the Bush Fires Board of WA by fax or internet within 4 hours of the data being received by Remote Sensing Services. These reports were followed up by mapping a total area burnt of about 20.6 million hectares, with 50% in the north west of the State. This information is complemented by bimonthly measures of green vegetation cover using the Normalised Difference Vegetation Index (Smith, 1994) and the Curing Index from individual overpasses.

Table 1: Total area burnt in the Kimberley region of WA: March to December, 1993 to 1996.

Year	1993	1994	1995	1996
Area Burnt (million ha)	2.13	10.54	15.12	10.49
*% Burnt	4.41	21.84	31.33	21.74

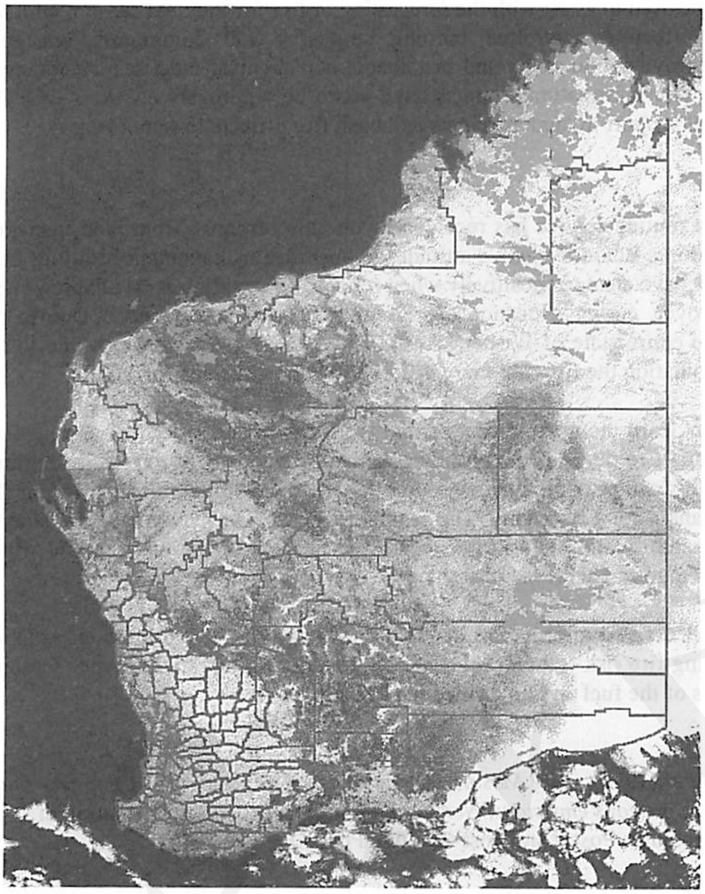
* Remote Sensing Services, Department of Land Administration WA





The geographic distribution of hot spots detected indicates the majority of bush fires are in the Tropical and sub-Tropical Savannas. The hot spots increase in May is a result of prescribed burning in the Kimberley initiated by the Bush Fires Board and CALM . The distribution of hots spots in 1996 extended south into the Pilbara, Great Sandy Desert, Gibson Desert and Great Victoria Deserts as a result of the good rains reaching these inland areas in 1996.

WESTERN AUSTRALIA - FIRE HISTORY 1996



3. Discussion

The fire scars mapped do not always accurately reflect the hots spots as their spatial resolution of detection is about 1000 metres compared with the resolution of hot spots of around 100 metres. This is a result of different detectors on the satellite being to use to map the change in reflectance cause by fire scars compared with the thermal anomalies caused by fire hot spots. This requires that to avoid high solar irradiance fire hots spots are detected using an early morning overpass while fire scars are mapped from the afternoon overpass when there is maximum solar irradiance.

Many of the hot spots in the south west area are associated with CALM's controlled burning of the under-story of the Jarrah Forests. They may not be detected as fire scars due to the small areas and the cover of the tree canopy. Fires located as hot spots can be mapped if they burn less than a pixel (Matson et al. 1987), whilst, fires need to burn an area greater than one pixel to be detected as a fire scar. Hot spot detection locates only currently burning fires, and, as fires are at their lowest intensity in the morning, a fire which is still burning may be at such a low intensity that it is not located as a hot spot fire. A fire may also be obscured by cloud or burning on a weekend and so will not be mapped. Evidence of a burn, on the other hand, is visible in an afternoon overpass for a period of weeks, therefore it is more likely to be located as a scar.

To answer queries and to integrate with other data sets such as vegetation and rainfall, it is important that the fire information derived from NOAA-AVHRR be maintained in a GIS. This will also enable ecological changes to be correlated with fire history and models to predict fire to be developed. The cumulative information can then be used to assist with the forecasting of fire for the next season, which is important when implementing effective controlled burning strategies and community education programmes .These all help to improve public safety and sustainable management practises. Accuracy of the various NOAA-AVHRR bush fire information products have yet to be vigorously checked. DOLA's priority is on providing operational support to land managers and bush fire officers in remote areas.

4. Conclusion

Provision of this information as a routine service has received favourable response from land managers and the field officers of the Bush Fires Board. Negative attitudes to bush fire management resulting from a lack of information to work with have changed positively when reliable information is available in near real time on green vegetation cover, curing, location of current fires and fire history. Due to the positive response, mapping of the entire state of Western Australia began in 1995, although due to the nature of the environment and population the fires are more difficult to detect in southern areas.

It is imperative that land managers learn more about fire, so that the location and spread of current fires can be monitored, models to predict fire developed and the ecological impacts of different fire regimes determined. Information such as this can provide a major source for the development of theories on fire leading to more informed fire management decisions. The results reported here have to be considered within limitations of the NOAA satellite and the priority to provide near real time information, which only NOAA's daily , regional coverage can achieve.

Integration of this NOAA-AVHRR derived information within a GIS with other geographic information is enabling methods for forecasting fire risk to be developed as a function of vegetation type, seasonal vegetation growth, present dryness of the fuel and time since the last fire.

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Effect of the Great Indian Desert on Acidic Deposition : The Changing Pattern

Sanjay KUMAR*

Abstract - The role of the Thar desert in influencing the acidic deposition in the North - West part of India is discussed. Chemical composition of rain water is analysed and the decreasing trend in desert derived anion concentration is correlated with acidic deposition in the last twenty years. Regional Acidification Information and Simulation (RAINS) computer model is used to calculate percentage of ecosystem threatened by the turn of the century. It is concluded that location and relocation of industries towards the Thar desert is likely to reduce the menace and will contribute towards development of socio-economic and climatological conditions of the desert.

Key words : Acidic deposition, Thar desert, ecosystem.

1. Introduction

Acidic deposition is a complex process and a necessary fallout of rapid economic growth. Asian energy demand is doubling every twenty years as compared to the world average of every twenty - eight years. The demand for electricity is growing even faster - two to three times faster than that of GDP. Over 80% of all energy is derived from fossil fuels which is a major source of sulphur dioxide emission. Similarly, increased activities in the transportation sector is responsible for NO_x emission. Airborne pollutants such as sulphur dioxide (≃70%) and nitrogen oxides (≃28%) are the main reasons for increased Hydrogen ion deposition. Nevertheless, oxidants such as ozone, hydrogen peroxide, and organic free radicals are intimately associated with dry as well as wet deposition. Reaction of these precursors with other chemical entities, often from photolysis, begin immediately on emission and, depending upon the emission rate, weather and air concentrations of all reactants, may proceed at different rates. In the mean time, the pollutants and their products are transported, diluted, deposited and augmented by new emissions along their path. Variations in acidic precipitation at a point is determined primarily by the meterological and geographical conditions, making it difficult to interpret short-term trends or to determine source receptor relationships empirically.

Acidic deposition is, therefore, defined as the total hydrogen ion unloading over a given period of time, eg. one year chemical and biological processes, both in soil and water, are badly affected by the hydrogen ion level. There are, however, natural mechanisms opposing a reduction in pH values called buffer action as long calcarious minerals abound in the soil. Numerous hypotheses of the detrimental effects of acidic deposition in various eco-systems by soil-mediated leaching below critical levels have been

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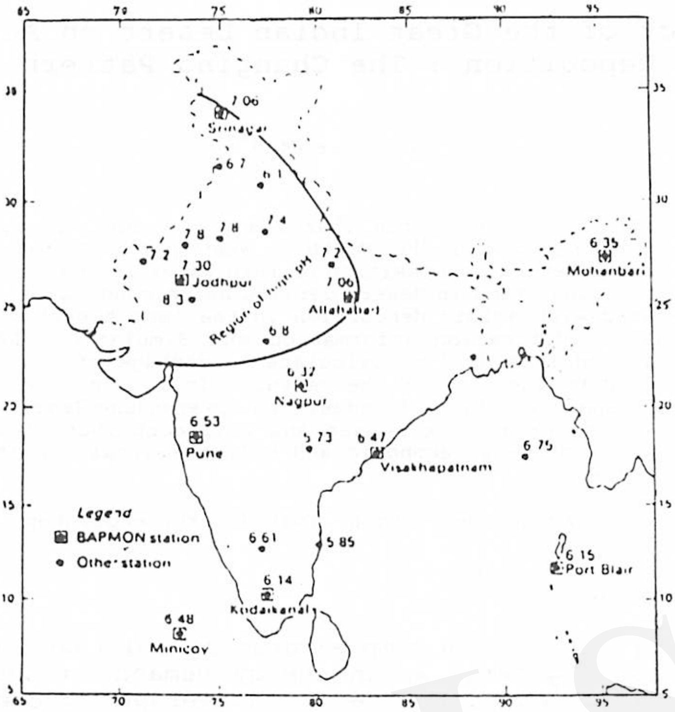

Fig. 1. Rainfall weighted mean pH value of BAPMoN stations.

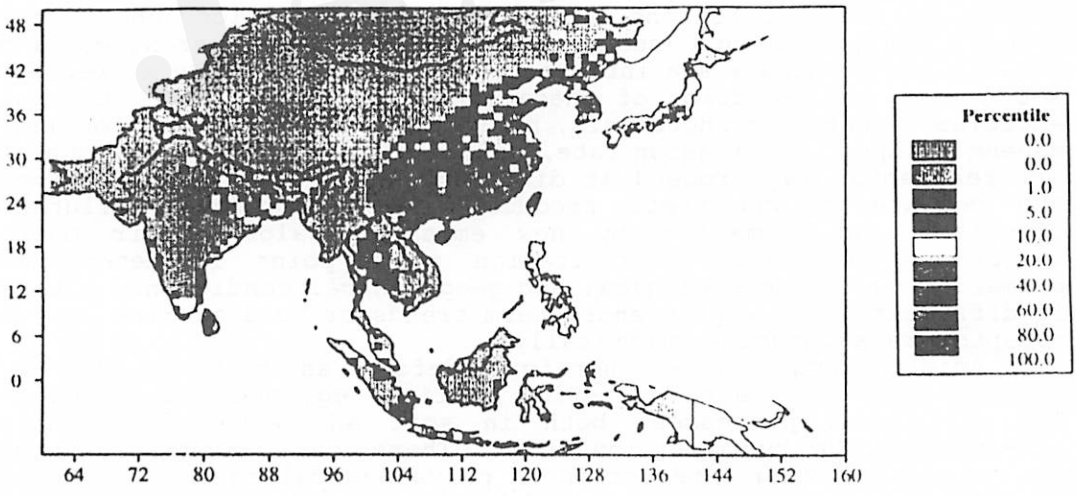

Fig 2: Excendance of area 2010 (base – Basic Control Technology)

proposed. These include leaching of essential nutrients such as K, Mg; release of monomeric aluminium into the soil solution; mobilization of trace metals; reduction of the efficiency of mychorrhizae, reduction in productivity of micro-organisms which decompose litter etc.

2. Background Trend of Acidic Deposition in North-West India: Influence of Thar Desert

In India, tropical climate conditions and alkaline-rich soil has neutralizing effect. Thar desert in the North-West part of the country, and sea derived aerosols, have been responsible in the past for maintaining the pH within the alkaline range. Higher temperature and sunlight increases the efficiency of atmospheric chemical reactions, particularly those transforming SO_2 and NO_x to sulphate and nitrates. An analysis of data obtained from the ten Indian Background Air Pollution Monitoring (BAPMoN) stations over the period 1974-84 shows that North-West India is exhibiting higher pH values (Fig. 1). The main reason behind these high pH values are the incursion of sand/dust particles into these areas from the Thar desert of Rajsthan. At Jodhpur and Srinagar, in addition to the rain chemistry measurements, high volume samplers were operated to study TSPM which revealed a significant positive correlation at 1% L.S. in both the cases. The regression analysis calculated for both stations can be represented by the following linear equations:

$$pH = (6.8550 \pm 0.1216) + (0.0015 \pm 0.0001)\ \bar{C} \text{ for Jodhpur}$$

$$= (6.7511 \pm 0.3051) + (0.0042 \pm 0.0004)\ \bar{C} \text{ for Srinagar}$$

Where $\bar{C}$ is TSPM concentration. TSPM collected from the Thar desert also revealed strong alkaline behaviour showing high concentrations of Ca^{++}, Na^{+}, K^{+} and Mg^{++} radicals. These equations show that any increase in pH value over the 6.7-6.8 range signifies the contribution of the Thar desert.

However, the background readings for pH precipitation have been showing a decreasing trend. Measurements in Delhi and Agra reveal that pH has decreased from 7.0 (1965) to 5.9 (1991) and 9.1 (1965) to 6.0 (1991), respectively. In Delhi, pH values upto 4.36 have been observed recently (Ravichandran and Padmnabha Murty, (1994)). An analysis of experimental results show that the ratio between anions and cations is always below one. This is probably due to the presence of HCO_3^- ions and organic free radicals. As the precipitation amount increased, the cations and anions decreased but the hydrogen-ion concentration increased. This is perhaps due to the scavenging of atmospheric constituents in earlier rains. In other seasons, the soil/desert derived cations are high enough to neutralize the acidity in the atmosphere.

3. Critical Load Projections and Location/Relocation of Emission Sources

Over the last few years, there have been important advances in our understanding of the steps which link the emissions of acidic gases to their subsequent depositions and fallouts. The Regional Acidification Information and Simulation (RAINS) computer model developed under the "RAINS - ASIA" project (Foell et al., 1995) is a step forward in this direction, providing negotiators and regulators with a full regional picture of the problems associated with the entire causal processes from energy systems and emissions through to the ultimate impact on natural and man-made systems. Earlier, a similar effort in Europe led to the signing of the Second Sulphur Protocol involving 33 signatories. The RAINS - ASIA model covers the countries between 10°S - 55°N latitude and 60°E - 150°E longitude. The temporal range is 1990 - 2020. The four basic modules are: regional energy scenario generation module (RESGEN); energy and emission module (ENEM); atmospheric transportation module (ATMOS); and impacts module (IMPACT). The Critical level (C2) is defined as the highest deposition level that is not likely to cause chemical changes leading to harmful effects on the ecosystem. By defining the relationship between chemical status and vegetation response, CL for that particular ecosystem is derived by a relatively sensitive approach using the steady state mass balance model.

An analysis of the data generated by the model shows that 85% of the ecosystem will be threatened by the year 2000 in a few pockets of North-West India surrounding Delhi even after best control technologies are used. (Fig.2). However, the expected increases in emissions, fallouts and, the resulting excess in critical loads can be used for the location and relocation of emission sources towards the Thar desert, such that the distribution will have least impact on these ecosystems and a positive impact upon socio-economic conditions, climate conditions and, afforestation efforts in the desert area.

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Environmental Auditing Beyond 'Range Condition': A Western Australian Perspective.

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Abstract: 'Range condition' relates to sustainable yield from a single(grazing) land use. It remains the only systematic, broad scale system of auditing the impacts of land use in Western Australia's arid zone. 'Range condition' does not accommodate the diversity of uses, values and ecological phenomena relevant to sustainable 'ecosystem management'. 'Rangeland health' has yet to accommodate these complexities. Community driven land use planning processes are needed. These should include assignment of specific land management objectives consistent with wider landscape and regional objectives. A range of integrated auditing procedures should address these hierarchical objectives.

Key words: values, ecological hierarchy, range condition

1. Introduction.

Approximately half (70 million hectares) of Western Australia (WA)'s arid zone has been used for the extensive grazing of domestic stock. The primary land management objective for this 'station country' has been sustainable yield of meat and fibre, mainly from sheep. Stations have usually been family-owned State Government leases ranging up to half a million hectares in area. The predominating wool industry has suffered declining terms of trade (STEVENS 1993) that show little sign of improvement in the foreseeable future.

ROY MORGAN RESEARCH CENTRE (1995) recently undertook a rangeland awareness survey commissioned by the Australian Rangeland Society. More Australians thought nature conservation values "are most important" (59%) than pastoral production (46%). This difference was greater in people under 35 years old and less for people over this age. Similar results were reported regarding which issues are "most urgent". Repairing degradation rated higher than ensuring financial and environmental sustainability of pastoral enterprises. One might tentatively infer that this represents a 'greening' of Australian attitudes towards the outback.

This article acknowledges wider community concerns beyond sustainable yield of meat and wool and the absence of parameters relating to them in environmental auditing. How to address this discrepancy is the central challenge. The terms 'range' and 'rangelands' are used here in an exclusively pastoral context. In the interests of brevity; recent, but widely established concepts in environmental management (eg Ecologically Sustainable Development-ESD and biodiversity) are not formally defined.

2. Traditional range condition assessment

As is the case in rangelands throughout the world, biophysical environmental auditing has focussed on the capacity of the land to sustain production under grazing by domesticated stock (NRC/NAS, 1984; NRC 1994; PRINGLE AND BURNSIDE 1996).

In Western Australia, most resources have been allocated to assessing perennial plant communities, augmented by rapid visual assessments of soil erosion. These assessments have occurred at monitoring sites within the Western Australian Rangeland Monitoring System (WARMS) (HOLM *et al.*, 1987) or at 'condition sites' and vehicular traverse points in regional ecological surveys (PRINGLE AND PAYNE, 1995). The focus on perennial plants has been adopted for this arid zone on the basis that seasonal variability confounds sensible ground assessments of ephemeral plants. Perennial plants also represent haystack feed for frequent poor seasons. However,

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some caution is urged in assuming that perennial plants are always a reliable indicator of long term sustainable yield (WILSON AND MACLEOD 1991; MILCHUNAS AND LAUENROTH, 1993).

3. Ecologically Sustainable Development and State of Environment reporting.

ESD reflects worldwide concerns about resource degradation and erosion of conservation values through inappropriate resource development. SoE reporting has been developed as a system of auditing the biophysical environment in this context (OECD 1994). This approach differs from traditional range condition in assigning priority to the maintenance of ecosystem services and biodiversity (collectively known as 'ecosystem management'), rather than the sustainable yield from any specific use. Recognition of multiple, overlapping and sometimes conflicting values of land underpins this new approach (KESSLER *et al.* 1992; NRC 1994).

The implications of sustainable 'ecosystem management' for environmental auditors of Western Australia's arid lands are that the focus must include the opportunity costs of any land use, as well as specific impacts arising from that use.

4. Range ecologists are trying to make their assessments more widely relevant.

The Committee on Range Classification of the National Research Council in the USA (NRC, 1994) has proposed a new approach to assessing the status of rangelands termed 'rangeland health'. It recommends;

'the term "rangeland health" be used to indicate the degree of integrity of the soil and ecological processes that are most important in sustaining the capacity of the rangelands to satisfy values and produce commodities".

Inherent in the NRC (1994) Rangeland health proposal is an assumption that one universally applicable system of assessment can be developed, irrespective of particular land uses and values. It also does not address scale issues (eg ALLEN et al., 1984; BROWN AND HOWARD 1996). Scale is an example of complexity that will confound attempts to develop a universally applicable approach.

5. Values and scale issues in an hypothetical example.

Analogous parcels of rangeland under different uses may have quite different land management objectives and consequently what is 'healthy' on one parcel may be 'unhealthy' on another. For instance, a vigorous community of introduced plants (eg *Cenchrus ciliaris* L., 'buffel grass') might improve sustainable yield on a station, or bring stability to a mine site generating dust which had previously impacted on an adjacent town site. However, on a nature reserve, these plants may be undesirable and represent a threat to native plants. What if the exotic plants could also provide excellent breeding habitat for local populations of regionally rare native fauna? Are they still undesirable and indicative of poor rangeland health?

To add further complexity, consider the issue at a landscape scale. What if the exotic plant community is in a station's paddock that lies up slope of a nature reserve? Suppose the reserve contains one of the few analogous habitats free of these exotics? Perhaps then the pastoralist management (paddock) objectives should be commensurate with the regional significance of the intact, reserved habitat. A single system of assessment seems incapable of dealing with these real complexities of scale and values.

Perhaps exotics are 'unhealthy'? Such a statement is inherently value-based. What is the assessment if the exotics have been responsible for stabilising severely degraded creek country? This might allow important ecological processes to be restored locally and lead to a decline in rates of damaging sediment output from the catchment onto coral reefs. Is this not a desirable trend in terms of ecosystem function (BUSBY *et al.*, 1996)?

The emergence of 'rangeland health' is evidence that range ecologists are responsive to the concerns of the wider community. It is a step in the right direction and its proponents have never suggested that it is a fully developed system, ready for widespread implementation (eg Busby *et al.*, 1996). However, the problem is really about reconciling community aspirations with land use patterns and land management objectives. These issues cannot be addressed by ecologists and bureaucrats in isolation, nor should they be.

6. The need for fundamentally new approaches to land use planning.

Contemporary patterns of land use and tenure are residual and out of kilter with the aspirations of the wider community (Wilcox and Burnside 1994). This reflects the historical inability of inflexible and bureaucratically centred land administration processes to respond to the views of stakeholder groups beyond traditional clients (Wilcox and Burnside, 1994).

Recent conceptual trends in resource management address discrepancies between land use patterns and objectives and public policy and wider community aspirations (eg Walters 1986). Fundamental changes to traditional environmental management are advocated. These include adaptive management, and community participation and empowerment. In other words, land administrators are encouraged to take the decision-making process to the people and allow for ongoing review.

Commonwealth and State Governments have recognised the need for change in this direction. They are funding research aimed at developing new processes with which to better allocate rangeland uses. In Western Australia, the Rangeways project aims to identify local and wider community groups and encourage them to express their values (Friedel 1997). The challenge will be to integrate these diverse and at times, conflicting values. It is hoped that computer software like Land Use Planning & Information System (LUPIS) (Ive *et al.*, 1989) will be tested and refined in this process. LUPIS is an excellent example of research scientists concentrating their efforts to develop technology for which there is an urgent, widespread need.

7. Important roles for ecologists within a new, broader context.

Ecologists and associated experts in developing technology should participate in, and be responsive to ongoing land use planning processes. The previous discussion about local management objectives regarding exotic species indicates how ecologists can help reconcile management objectives with a range of values and across spatial scales. They can provide insights as to how higher level (eg landscape and regional) objectives can be implemented locally, or how local objectives might compromise or contribute to higher level objectives.

Ecologists have a critical role in developing auditing procedures likely to reveal whether a range of nested land management objectives are being met. This might involve close co-operation with experts in technology. For instance, the vastness and generally low economic return per hectare from arid zones means that quantitative broad scale auditing will rely on remote sensing techniques (eg Pickup *et al.*, 1993). Geographic Information Systems will also be needed to keep track of increasingly diverse land use and associated management objectives.

8. Concluding remarks.

This is a new era in environmental management which focuses on sustainability, ecosystem management and State of Environment reporting. These new perspectives recognise complexity with regard to diversifying values and uses for arid lands and their hierarchical context. Adaptive processes are being developed in order to reconcile land use patterns and land management objectives with sustainability in its integral forms (eg ecological, social and economic). Environmental auditing procedures should be developed and targeted in a similarly adaptive, nested and integrated fashion as part of this process! A single, universally applicable procedure cannot do this.

9. Acknowledgments.

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The World's Arid Areas - Global and Regional Assessment of the Past, Present and Future

Poster Papers

沙漠研究 7S, 39-42 (1998)
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Sustainable Pastoral Land Use in an Arid Climate
- A Shiny, New Toolbox!

Ken LEIGHTON* and Sandra VAN VREESWYK**

Abstract - The semi-arid and arid areas of Western Australia (W.A.) could well become an extension of the already expansive desert which characterises the centre of Australia. If pastoral land management is not sympathetic to natural environment changes we could expect to see vegetation depletion to a level where there can be no recovery. Already surveys within the pastoral areas are showing that regional condition is well removed from the optimum. Continued monitoring of this change and possible improvement in range condition is important, particularly to the pastoral industry whose long term viability is based on the economics of raising domestic stock on native vegetation. It therefore becomes the imperative of every stakeholder to sustainably manage the resource. The rangeland survey programs can provide the basis of this management but other tools are readily available. Processed satellite data from both the Vegetation Watch and Fire Watch initiatives are available at regular intervals; pastoral lease (economic) models are available on demand; and stocking rate research results have been published. Consequently the land manager need not be ill-informed - rather he needs to work smarter. The government provides many services, mostly at nominal cost, to encourage the best use of the arid lands.

Key Words: rangelands, pastoralism, management

1. History of pastoral occupation

The first commercial use of the rangeland areas of W.A. started soon after nineteenth century exploratory expeditions reported the existence of favourable grazing conditions inland. By the 1890s pastoralism had become established along many of the major river system frontages which provided a ready supply of water and productive pastures. As land along these rivers became scarce there was a general push inland and such areas as the Goldfields were occupied, however it would not be till the end of the 1960s before all land deemed suitable for pastoralism was released. The need for good supplies of water and fencing to control stock became more imperative as this inland development expanded. And so the typical pastoral station as we know it today came into existence.

In the early years of the pastoral industry cheap labour, low development costs, and high returns encouraged lessees to stock at levels which inevitably proved to be unsustainable. A severe drought from 1935 to 1942 affected all country south of the Pilbara with the result that overstocking was blamed for widespread serious degradation of the vegetation and soil erosion. The Royal Commission of 1940 heard evidence that within the Murchison-Meekatharra region 75% of saltbush (*Atriplex* spp.) and 25% of the acacias (*Acacia* spp.) had died as a direct result of drought and overstocking. This dramatic decline in the ability of the land to support the previous levels of stock, necessitated a change of management strategies. It had become immediately apparent that the initial estimations of the carrying capacity of the land were grossly exaggerated.

In the Kimberley, although not affected by drought, the concentration of stock along the river frontages was, by the 1940s, causing degradation of the fragile alluvial systems. Widespread soil erosion and the subsequent decline of grasslands became evident. Facilitated by the removal of all domestic livestock, amelioration of the problem has come at considerable effort and expense.

Fire, by both natural and unnatural causes, has played an important role in the development of the Pilbara and Kimberley ecosystems over millennia. However, in the years since pastoralism began the regime has undergone drastic change with the result that vegetation composition has changed forever. Similarly the introduction of foreign species eg buffel (*Cenchrus ciliaris*) has changed the face of the Pilbara rangelands and considerably altered the carrying capacity of the land and been instrumental in stabilising some erosion susceptible landscapes.

The excesses of the past have profoundly altered the shape of the rangelands. Both pastoralism and mining have rendered unproductive large tracts of land and even though the current land managers may not have been responsible, community expectations are that they should instigate remedial action. In many instances local community groups such as Land Conservation District Committees are applying themselves to this task with some success. Mining companies are also directly involved with sponsoring active participation in rehabilitation processes. Coming from this new wave of community interest in the well-being of the rangelands is a heightened government imperative of 'doing the right thing'.

Legislative requirements for natural resource protection and conservation exist under numerous acts of Parliament with some being rigorously applied eg Soil and Land Conservation Act (land conservation notices). However, the preference would be to encourage firstly that land users manage the environment within its capabilities ie sustainably, and secondly that when problems are recognised remedial action be instigated using government and

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community assistance programs voluntarily rather than by coercion. To this end the government provides a number of services and tools which are available to all land managers.

2. Pastoral lands products and services.

2.1 Rangeland survey program The aim of the rangeland survey program is to map and describe the rangelands of Western Australia, and to assess the condition of the vegetation and soil. The program is run jointly by the Department of Land Administration and Agriculture Western Australia. To date, over two thirds of the state's pastoral rangelands have been surveyed (Table 1.)

Table 1. Resource condition summaries for regional rangeland surveys

Region surveyed (and year commenced)	Total area (km^2)	No. of traverse assessments	Severely degraded and eroded area (as mapped)		Resource condition classes (% of traverse assessments)		
			km^2	%	Good	Fair	Poor
Gascoyne (1969)	63,400	2,426	1,205*	1.9*	32	53	15
West Kimberley (1972)	89,600	4,532	2,000*	2.2*	20	50	30
Eastern Nullarbor (1974)	47,400	1,273	0	0	50	10	40
Ashburton (1976)	93,600	8,608	534	0.6	50	34	16
Carnarvon Basin (1980)	74,500	10,952	647	0.9	45	32	23
Murchison (1985)	88,360	13,441	1,560	1.8	21	37	42
Roebourne Plains(1987)	10,216	1,172	233	2.3	51	27	22
North-eastern Goldfields (1988)	100,570	10,470	452	0.4	39	32	29
Sandstone-Yalgoo-Paynes Find (1992)	94,710	9,435	145	0.2	45	32	23
All areas surveyed	661,840	62,309	6778	1.0	39	34	27

* Not mapped, estimate only.

Products from the surveys include detailed reports, land system maps, and station plans showing station infrastructure and land system boundaries. The land system maps provide a regional overview of natural resource information for land users, land administrators, research institutions, mining and engineering companies, conservation groups etc. The station plans and recommended carrying capacities can be used by land managers to develop station management plans which take capacities and limitations of different types of country into consideration. Stocking rate workshops are held in conjunction with local Land Conservation District Committees, results from these workshops are used in part to set the stocking rates derived for the survey area. Survey information is used for the preparation of Range Condition Reports, which informs potential lessees and land administrators of the capability and condition of the lease.

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Ken Leighton, Dept. of Land Administration, Midland, Tel +61 8 9273 7130 (mapping)

2.2 Monitoring The Environmental Monitoring Group within Agriculture Western Australia provides information on the condition of the state's rangelands to pastoralists, Government and the wider community. Range condition (ie thae health of the soil and vegetation) is monitored over time through the Western Australian Rangeland Monitoring System (WARMS). This system consists of a series of permanent ground-based sites located throughout the pastoral area, which are regularly visited. It provides information on vegetation composition and more recently, soil surface characteristics, and the impacts of management on these rangeland resources. Monitoring data in this format has been collected since 1984. This project has incorporated the development of an appropriate analysis technique for determining changes in rangeland vegetation over time. At present, sites have been installed on over

250 pastoral leases with many sites having been visited on more than one occasion. New sites are still being installed, with the final total of 1700 sites on over 470 pastoral leases to be reached by the year 2000.

Monitoriong sites which show change may be influenced by factors that can be managed, such as grazing intensity or fire, or by unpredictable natural events such as hailstorms. The WARMS trend summaries provide land managers with improved information relating to ecosystems changes and the impacts of management on the rangeland resource.

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2.3 Property Management Planning A nationwide Property Management Planning (PMP) campaign was established to improve the pastoral industry's ability to buffer the impacts of the increasing environmental and economic pressures it faces. This would be achieved by providing advice in the form of 'whole of property' planning which aims to increase pastoralists' management and planning abilities. Agriculture W.A. has been involved in station management planning for many years. In 1996 a change in focus occured from individual planning to workshops with a PMP officer in each district office, and an integrated approach across the whole southern rangelands. Four PMP officer's have been appointed throughout the southern rangelands.

A series of planning workshops for small groups of neighbouring stations has been developed. These include one day workshop modules on planning techniques, financial planning, resource management, stock management and implementation of the plan. Working in groups allows managers to learn from each other and discuss the ideas presented.

Pastoralists can have the latest maps for their stations prepared using Microstation® in consultation with a PMP officer. Land system information is also available in digital form allowing for the calculation of areas of pasture types and paddocks, and the most sustainable stocking rate.

Contact : Property Management Planning Officers at Agriculture W.A. district offices.

2.4 Computer packages Various computer models have been developed for use in the rangelands. Packages which are commonly used in W.A. include :

- IMAGES - developed by Agriculture Western Australia to give a measure of the impact of various stocking rate/range condition combinations on the vegetation resource. Currently probability distributions of vegetation response to various management strategies are being developed to allow a measure of environmental risk to be made for each management strategy. The model is sensitive enough to provide a measure of the impact of short term tactical management changes on the vegetation resource. The analysis provides a measure of the critical vegetation thresholds which can be linked to animal numbers from CSIRO's Rangepack Herd-Econ package to set the animal numbers that can be carried for particular season types.
- AUSTRALIAN RAINMAN - developed by Queensland Department of Primary Industry in conjunction with Agriclutur Western Australia and the Bureau of Meteorology to provide land users with a means to examine historical rainfall records, forecast the chances of seasonal rainfall and identify climatic risks and opportunities. It features tables, graphs and maps, information explaining the effects of the Southern Oscillation and sea surface temperatures, monthly rainfall for most pastoral stations in the southern rangelands and the option to enter your own rainfall data.
- PROJECT SPREADSHEET - developed by Agriculture Western Australia as a spreadsheet in Microsoft Excel®. This spreadsheet provides for the projection of flock or herd numbers over 6 seasons using lambing/calving rates, death rates, sale prices and weights and so on. The seasons can be adjusted to be poor, typical and good which also affects the births, deaths, prices and weights and so on. There is a section to add cashflow budget information which is also projected for the 6 seasons. Other pages include bank loans and stockfirm accounts and an assets and liabilities page. A final page shows business health indicators such as equity, liquidity and so on which are represented as tables and graphs.
- GROSS MARGIN ANALYSIS SPREADSHEET - developed by Agriculture Western Australia as a means to perform gross margin analysis easily to analyse different production options. This spreadsheet is set up to run in Microsoft Excel®. A main benefit is the sensitivity analysis which presents the gross margin for a range of prices, weights, lambing/calving percentages and wool cuts.

Contact : Property Management Planning Officers at Agriculture W.A. district offices.

2.5 Grazing research Agriculture Western Australia has carried out a number of grazing trials in the rangelands. These include trials on stocking rates, deferred grazing and spelling, feral goat grazing, and kangaroo management. Cattle producer demonstration sites have also been established. The agency has held many field days and workshops which have gathered together local knowledge on topics including improving productivity, resource management and the use of particular types of rangeland vegetation, such as spinifex pastures and saltbush and bluebush pastures.

Contact : District leaders at Agriculture W.A. district offices.

2.6 Diversification In times of increasing environmental and economic pressures on the pastoral industry, there is increasing interest in finding alternative land uses to supplement station income. Agriculture Western Australia have supported this trend by providing advice on alternative business enterprises.

Contact : Dr Katherine Egerton-Warburton, Agriculture W.A., Meekatharra Office, Tel +61 8 9981 1105

2.7 Vegetation Watch Ground-based methods of monitoring can now be complemented with information from satellite images. These images are collected at regular time intervals and provide routine monitoring of vegetation at a continental scale. Sequences of satellite images can be processed and analysed to provide information on changes in vegetation condition through time. In different regions, this information has been used to identify areas where shrub invasion has occurred, and areas where perennial grasslands have recovered from heavy grazing pressure. Although the image maps do not provide direct ecological interpretation, they are used to extend the knowledge gained from ground data to cover large areas and to direct attention to areas where changes have occurred.

Contact : Dr Richard Smith, Dept. of Land Administration, Remote Sensing Services, Tel +61 8 9 340 9342

2.8 Fire Watch This program is similar to the Vegetation Watch initiative which uses processed and corrected NOAA-AVHRR satellite data. At a resolution of about one square kilometre regional, statewide or national overviews are produced and routinely inspected to detect fires in near real time. Using the night near infrared (NIR) band fire hot-spots are identified and the information passed to fire management authorities, whilst daylight NIR data is used to produce fire histories. Fuel load build-up can also be estimated as a precursor to the opening of the fire season and can be used to manage burn operations.

The value of this program to the land manager is the archive of fire histories and by combining these with vegetation maps an assessment of fire risk and potential damage can be made.

The program is currently being used by the W.A. Bush Fires Board and the Department of Conservation and Land Management in the Kimberley, and the Northern Territory Bush Fires Council to monitor fires and to develop fire management strategies.

Contact: Ron Craig, Dept. of Land Administration, Remote Sensing Services, Tel +61 8 9340 9346

3. Internet addresses

This site has a list of the complete range of Dept. of Land Administration products and services available - **http:/www.dola.wa.gov.au**

This site has a range of information from Agriculture Western Australia - **http://www.agric.wa. gov.au**

This site (AUSLIG) contains various information including maps, aerial photographs, digital map data and satellite imagery, with a price list - **http://www.auslig.gov.au/index.html**

This site is the Remote Sensing Services Centre website in Perth. It has information on satellite images, including fire history and pasture condition index - **http:/www.per.dms.csiro.au/rsac.html**

This site contains the Bureau of Meteorology Web site with rainfall charts for Australia, the Bureau of Meteorology Gopher, with the latest satellite images, synoptic charts and probability of wet/dry conditions for W.A., and the QDPI LongPaddock with analyses relating to the Southern Oscillation Index and sea surface temperatures - **http://agweb/progserv/natural/climate/netrain.html**

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Global Water Erosion Modelling Using Remote Sensing and GIS

Krishna PAHARI* and Shunji MURAI* *

Abstract - Land degradation is one of the most pressing environmental problems of the world and soil erosion due to running water is one of the key aspects of land degradation. This paper describes an attempt to analyze the spatial distribution of global water erosion with the use of remote sensing and a Global GIS, on the basis of a generalised equation proposed by the authors. An analysis is also made to demonstrate the human impact on soil erosion by developing the soil erosion models for the actual erosion status and potential erosion under natural conditions if there were no human impacts.

Key Words: Remote Sensing, GIS, DEM, Soil Erosion

1. Introduction

Land degradation is recognised as one of the major environmental problems of the world and soil erosion due to running surface water is one of the key issues of land degradation. However, spatial study on land degradation, specially on global level is largely inadequate.

The emergence of remote sensing and Geographic Information Systems (GIS) provide new opportunities for studying the environmental problems on a spatial and temporal basis, including the land degradation. This has specially been useful in studying the environmental phenomena over larger areas such as at regional, national or global levels.

2. Concepts and Methodology

2.1 General Equation for Water Erosion Modeling Soil loss due to water erosion is one of the major causes of land degradation specially in mountainous terrain conditions with medium to high rainfall. The Universal Soil Loss Equation given by Wischmeier and Smith (1978) is the most widely used method for estimating the amount of soil loss through water erosion. According to this, the annual soil loss in tonnes per hectare per year (E) is given by:

$$E = RKLSCP$$

Where, R is the rainfall and erosivity factor, K is called the soil erodibility factor, L is the slope-length factor, S is the slope steepness factor, C is the land cover and management factor, and P is the conservation practice factor.

The above equation can be successfully applied to quantify soil loss in a small area for local level studies. However, for the global scale study, it is not possible to use this equation without modification, mainly due to the unavailability of data to sufficient detail. However, some generalisation can be made from the above equation to study the global phenomenon.

2.2 Generalized Equation for Soil Loss Assessment at the Global Level To make global assessment of water erosion the soil loss equation can be written in a more general form as follows:

$$E = f(\,rainfall,\ topography,\ soil,\ landuse\,)$$

Specifically, the authors have proposed the following equation for assessing water erosion at the global level:

$$E = RKTC$$

Where, E is the annual soil loss in tonnes/ha/yr and R, K, T and C are the rainfall erosivity factor, soil erodibility factor, topographic factor and land cover factor respectively.

2.3 Assessing Factor Values

Rainfall Erosivity Factor (R) This factor represents the potential of the rainfall to cause soil erosion and is a function of average annual rainfall and the maximum rainfall intensity (usually taken for 30 minutes).

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However, since a global dataset is not available for 30-minute rainfall intensity, the following method has been used for computing rainfall factor based on the annual rainfall data (Morgan 1986):

a) For high rainfall areas (with mean annual rainfall value exceeding 2000 mm), compute the mean annual erosivity(in J/m2) by using the equation 9.28P - 8838, where P is the mean annual precipitation in mm, then multiply the above value by the maximum 30-minute intensity I30, assuming I30 = 75 mm/hr as the maximum value recommended by Wischmeier and Smith (1978).

b) For low rainfall areas (with mean annual rainfall less than 2000 mm), since this method gives misleading results for such areas, the factor is calculate by using the equation

R = 0.5 P, where P is the mean annual rainfall in mm.

For the annual rainfall data, the mean annual rainfall data interpolated into image surface data based on the point data available for a total of 1860 different locations distributed over the world have been used.

Soil Erodibility Factor(K) It is a function of soil texture, its structure, permeability and organic matter content and is given by the following equation for detailed studies at the local level.

K = M1.14 (10-4)(12-a)+3.25(b-2)+2.5(c-3)

where, M,a,b and c are coefficients depending on the particle size, organic matter content, soil structure and permeability respectively,

At present, since global data are not available in such details, the K factor value has been computed from the broad soil categories from the digital soil map produced by FAO.

Topographic Factor (T) The equation for the topographic factor(LS) given by Moore and Wilson (1992) is as follows:

$$LS = (L/22)^m (10.8 Sin\beta + 0.03) \text{ for slopes} < 9.0\%, \text{ and}$$

$$LS = (L/22)^m (16.8 Sin\beta - 0.50) \text{ for slopes} >= 9.0\%,$$

β = slope gradient in degrees,

m = F/(1+F), and

$$F = (Sin\beta / 0.0896) / (3 Sin^{0.8}\beta + 0.56)$$

where, L = length of slope in meters, and

S = angle of slope in degress.

A global Digital Elevation Model originally at a resolution of 5'x5' and then resampled to 10'x10' grid was used for topographic analysis in this study. Due to the coarse resolution of the DEM data, it is not possible to calculate the slope steepness and slope length directly from the DEM with reliable results, therefore the surface topography was represented by using the standard deviation of the height data in the global DEM by using a moving 3x3 window for each pixel in the DEM image. The standard deviation was then correlated with the corresponding slopes and slope-lengths based on the ground truth data from a number of known points and then the calculation of topographic factor was made (Table 1).

Table 1: Standard deviation from Global DEM, slope, slope-length and the topographic factor

Standard deviation from Global DEM (meters)	Corresponding slope(%)	Slope-length (meters)	T factor
0 - 25	0 - 2.5	600	0.30
25 - 50	2.5 - 5.0	500	1.28
50 - 100	5.0 - 10.0	400	3.27
100 - 150	10 - 15	300	6.52
150 - 200	15 - 20	200	8.91
200 - 300	20 - 30	150	11.24
300 - 400	30 - 40	100	12.83
> 400	> 40	100	14.81

Land Cover Factor (C) This factor represents two aspects. The first is the land use or land cover of the ground, and the other is the land conservation or management practices. The land cover of the ground can be estimated by using the satellite data, mainly the NOAA GVI data. In this study the land cover map developed by Murai and Honda (1990) based on the dynamic analysis of GVI data has been used. However, it is not possible to estimate the land conservation practices from the available global data to the desired level. Therefore, the factor values (Table 2) based on this are only the representative values of the broad categories.

Table 2: Land cover factors

Land cover type	C factor
Forest	0.002
Grass land	0.030
Semi-desert	0.100
Desert	0.400

3. Results and Discussion

3.1 Actual Erosion Map The actual erosion map has been developed by first generating the images for each factor based on the principles outlined above and then generating the image for erosion (in tonnes/ha/yr) by multiplying the above factors. In order to make it more understandable, a simple level slice is made from the erosion map to generate an image showing range of soil erosion with different levels.

3.2 Potential Erosion Map under Natural Condition In order to get some idea about the extent of human impact, an analysis was also made for the potential soil erosion under natural conditions. For this purpose, the potential natural vegetation map based on climatic parameters by considering the Aridity index (Pahari and Murai, 1995)was utilized. The values of the C factor were used in accordance with the land cover under the potential natural vegetation. Since other factors, that is the factors for rainfall, topography and soil are largely unaffected by human activity, the values for these factors were taken to be the same as in the above analysis. Finally, by multiplying the new C factor with other factor values, an image was generated for the potential soil erosion under natural conditions.

The results of actual water erosion and that under potential natural conditions have been given in Figures 1 and 2 and Table 3.

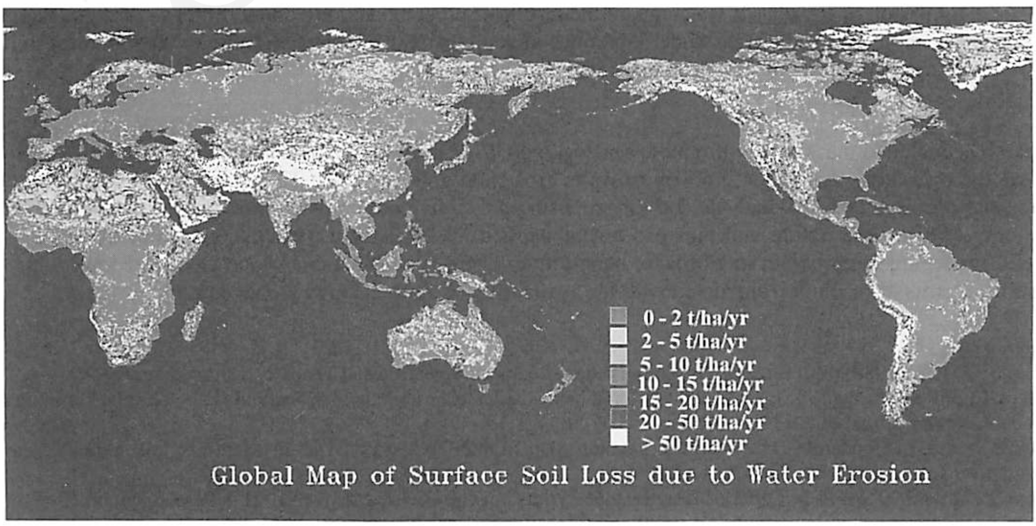

Figure 1: Global map of surface soil loss(actual) due to water erosion

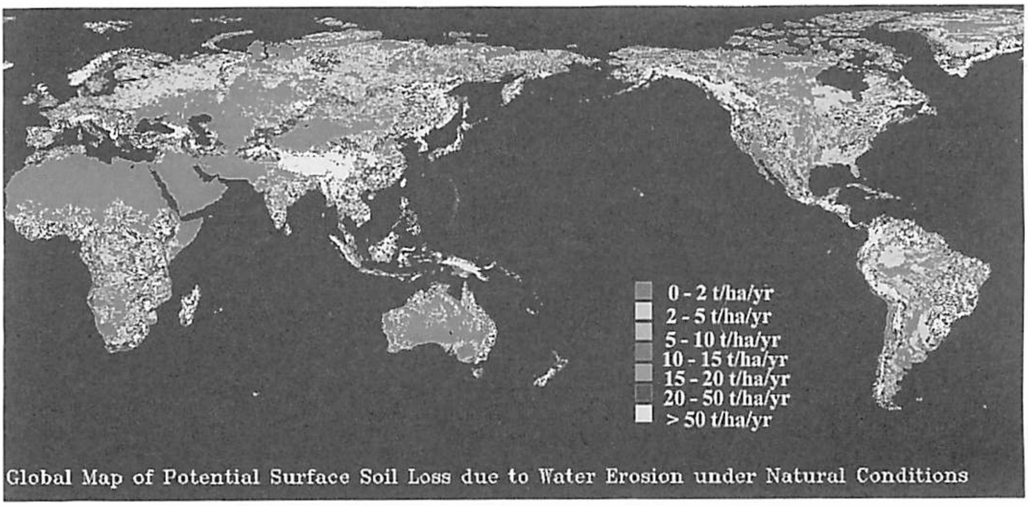

Figure 2: Global map of potential soil erosion under natural conditions without human impact

Table 3: Areas under different erosion categories under the actual (present) and potential natural conditions

Erosion rate (t/ha/yr)	Percentage area	
	Actual erosion map	Potential erosion map
0 - 2	53.9	61.1
2 - 5	13.0	15.0
5 - 10	8.9	8.2
10 - 15	3.9	3.8
15 - 20	3.2	3.3
20 - 50	8.1	6.0
> 50	8.9	2.6

3.3 Discussion of Results If we compare the results of potential soil erosion with those of the actual soil erosion, it is obvious that the areas under high rates of soil erosion have increased due to the human activities while those under mild to moderate soil loss rates have decreased.

4 Conclusion

It can be concluded that the use of remote sensing and GIS is useful for global water erosion modelling so as to see the overall picture of the problem of water erosion at a global level. This is helpful in identifying the hot spots for more detailed analysis and for proposing preventive or curative action. Even though the results are only of a general nature and thus can not be applied in detail for a particular location, the results are useful for seeing the problem in a broader perspective. There is considerable scope in further improving the results in terms of resolution and detail with the availability of more detailed global datasets.

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The Characteristics of Rainfall in the Republic of Djibouti

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Abstract - The physical properties of soils, as well as hydrological and meteorological conditions, are very important factors for desert greening. From this point of view, we have examined hydrological statistical analysis in order to evaluate the characteristics of rainfall, such as intensity and distribution, for effective utilization of water resources in Djibouti. As a result, the distribution of rainfall were in such good agreement with the elevation above the sea level and annual rainfall increased almost linearly with increasing the elevation. Finally we introduced a method to evaluate the areal rainfall by using equations (1) and (2) coming up.

Key Words : Desert Greening, Areal Rainfall, Mean Elevation Method, Irrigation, Sustainable Agriculture

1. Introduction

In order to clarify the characteristics of rainfall in the republic of Djibouti, we estimated the probability of the annual rainfall and the highest daily rainfall, based on the hydrological data. Thus, as a result, it was found that, although the amount of annual rainfall was small, the intensity of the rain was so high, that it could be compared to the Japanese intensive rain during the rainy season (Takahashi, et al.,1994).

Therefore, it became clear that, improving the conditions of the Wadi (stream of water flowing only during rainy season) for the irrigation purposes, was important for greening. To achieve those purposes we had better estimate the areal rainfall, but the rainfall measurement stations were few, and could not cover all the area. Thus additional stations are needed. Generally, it is not easy to collect hydrological and meteorological data for whole the country, much less for specific area, the same applies to several countries in Africa.

According to the previous reason, we introduced the evaluation of areal rainfall for irrigation purposes even though those data were not sufficient.

2. Study area and methods

2.1 Study area

The area is divided into 8 spots, from which we collected the data used for evaluation of the rainfall characteristics in Djibouti.

These 8 spots (Djibouti Serpent, Djibouti Aerodrome, Loyada, Yoboki, Dorra, As-eyla, Arta and Randa) are shown in Fig. 1.

Table 1 shows the latitude, longitude, elevation and distance from coastal line.

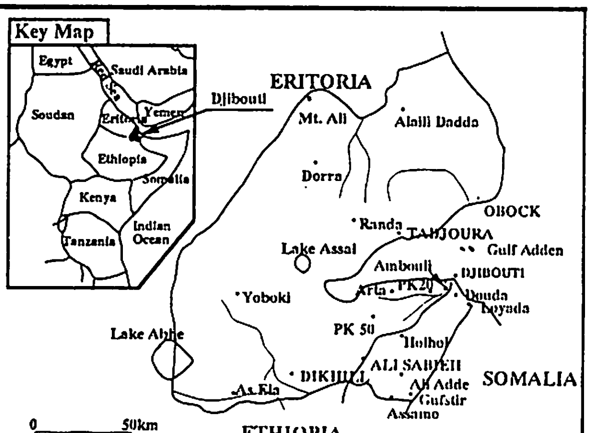

Fig. 1 Location map of main town and meteo. station

2.2 Methods

As before hand, we described the hydrological and meteorological data(Ministry of Agriculture and Rural Development in Djibouti,1992) collected from 1900 to 1990 for the 8 stations of the study area, during that period of time we were only using the data of 1958 to 1963 (excluding

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Table 1 Location of Stations

Station name	Latitude	Longitude	Elevation (m)	Distance from coastal line (km)
DJIBOUTI-SERPENT	11° 36′	43° 09′	5	0. 1
DJIBOUTI-AERODROME	11° 33′	43° 09′	8	0. 5
LOYADA	11° 28′	43° 15′	15	0. 1
YOBOKI	11° 30′	42° 06′	230	45. 1
DORRA	12° 09′	42° 28′	295	54. 3
AS-EYLA	11° 00′	42° 06′	350	73. 2
ARTA	11° 31′	42° 50′	705	6. 0
RANDA	11° 51′	43° 39′	920	17. 7
DIKHIL	11° 06′	42° 22′	500	64. 5
ASSA-GAYLA	12° 12′	42° 38′	612	52. 8

those of 1962) for the purpose of ev-aluation of rainfall characteristic. The method we used for the evaluation was based on the calculation of variation of annual and monthly rainfall collected from the eight stations, so that we could base on those data, estimate the distribution of the rainfall in Djibouti.

3. Results and Discussion

3.1 Rainfall Distribution

(1) Point Rainfall

Table 2 shows the maximum, minimum, average, difference of max. and min. and the variation of the rainfall at the 8 stations, these values were used to determine the characteristics of rainfall in Djibouti.

Table 2 Characteristics of Annual Rainfall

	Max. Annual Rainfall (mm)	Min. Annual rainfall (mm)	Difference between Max. Annual Rainfall and Min. Annual Rainfall (mm)	Average Annual Rainfall (mm)	Variation (%)
SERPENT	155	52	103	114	36. 0
AERODROME	258	58	199	142	51. 4
LOYADA	258	64	194	121	59. 0
YOBOKI	211	59	152	137	41. 0
DORRA	176	147	29	158	7. 2
AS-EYLA	246	178	68	199	12. 4
ARTA	453	147	306	244	45. 5
RANDA	345	198	147	280	16. 8

Remark;"Variation"means ratio of Max. Annual Rainfall and Min. Annual Rainfall

From the previous value, we realised that the rainfall average was higher in the high land than the low land. It is said that the amount of rainfall increases when the elevation increases even in the same area(Fukui,1938). The range of the variation varies from 7.2 % to 59% this wide range is of the characteristics of the arid land in the tropical zone.

According to the large value of the variation between annual rainfall and the elevation, it is clear that the low the land , the low the amount of rainfall. The main reasons of the high range of variation are thought to be due to the stability of the dry climate in arid zones which is related to the elevation of the land. For the evaluation we calculated the average and the variation of the monthly rainfall for each station.

Basing on the previous calculation, the area can be divided into three types of monthly rainfall zones :

i) elevation of 200 m or less, there is more rainfall from November to March,

ii) elevation from 200 m to 500 m, in this zone there is more rainfall from July to September,

iii) elevation of 500 m or more, the rainfall is high from May to June.

Based on the previous classification, the distribution of monthly rainfall is depended on the elevation of the land.

(2) Elevation and Rainfall

As discussed previously that the rainfall was higher in the mountainous area than the low land, and based on the data collected from the several stations, we plot a graph (see Fig.2).

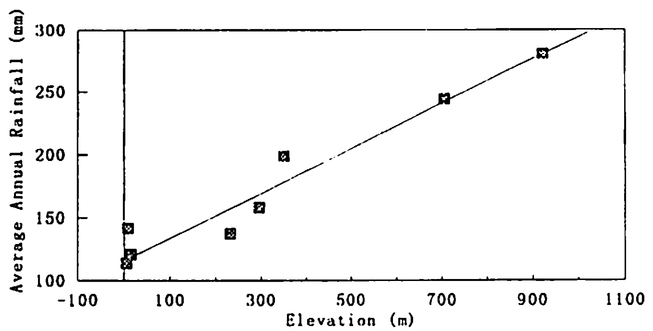

Fig.2 Relationship between Average Annual Rainfall and Elevation

Fig. 2 shows the relation between elevation and average annual rainfall. The average annual rainfall increaes almost linearly with increasing the elevation.

The relation is represented with the following equation(1):

$$Re = 119.59 + 0.17\ h \quad \text{--------------------} \quad (1)$$

(r^2 =0.94) : correlation coefficient.

Re : estimated average annual rainfall , h : elevation (m)

It appears that the relation between annual rainfall and the elevation is closely high for each area.

The fact can also be described geographically, that the higher the elevation, the cooler the climate, which lead to the rain. In Djibouti, it is thought that the wet air rises through the mountains leading to rainfall by the adiabatic expansion which increases the annual rainfall in those area comparing to the area of low land. It is noticed that the rainfall on the mountainous areas, increases to some elevation at which it reaches the peak of the amount of rainfall, and then it decreases, but this does apply to the same area in Djibouti.

Generally it is said that the maximum rainfall in the tropical zones occurs at the elevation of 1000m, (Yoshino,1990) but the study area is located in area where the elevation is less than 1000m. Using the previous equation(1), we estimated the areal rainfall for the purpose of irrigation in Djibouti.

By using the same equation we have drawn the annual rainfall contour map(see Fig.3).

From the map, it is found that the rainfall is

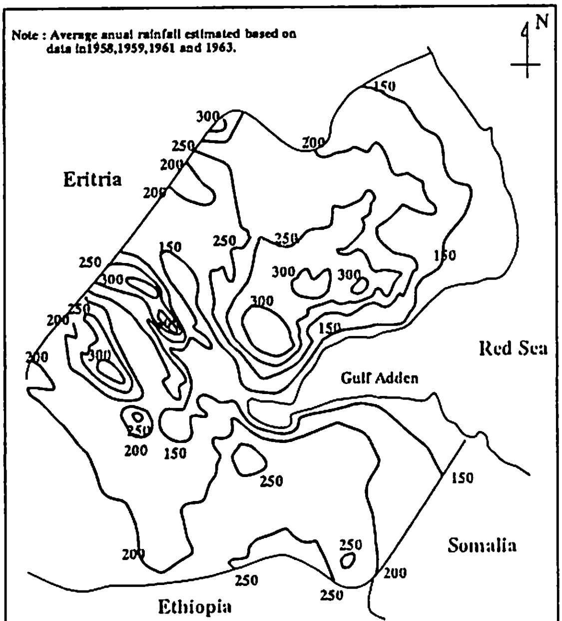

Fig. 3 Annual Rainfall Contour Map

higher in the north-west of the country, contrarily, the rainfall is 250mm or less in the southern part, therefore it appears hard to introduce the crop cultivation and the greening to the southern part of Djibouti.

We can estimate the areal rainfall basing on the contour map of the annual rainfall in Djibouti.

In general, there are several methods to calculate areal rainfall. Among those methods we used the mean elevation method, which is used for long term data and the linear relation between rainfall and elevation.

The equation led is the following bellows:

$$Ra=119.59+0.17ha \quad \text{-----------} \quad (2)$$

Ra : estimated areal rainfall (mm)

ha= Σ (Ai x hi)/ Σ (Ai), in which : ha is mean elevation (m) ,

: Ai is average area(km^2).

: hi is average elevation at each station(m).

: n is number of stations.

Using the equation above, we can calculate the areal rainfall at each station in the study area in Djibouti.

4. Conclusion

According to the difference between the elevation and the rainfall in the study area, and using the previous equations, and contour map, we came up to locate the suitable area for greening and crop cultivation in Djibouti.

We can estimate the areal rainfall for irrigation purposes by using equation(2).

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The World's Arid Areas - Global and Regional Assessment of the Past, Present and Future

Papers Not Presented at the Conference

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Desertification and its Developing Trend on The Tibetan Plateau,China

Shen Weishou *, Dong Guangrong* and Li Sen*

Abstract There exists 204740km² of various desertified Lands which covers about one-fifth of the Plateau's land surface. Studies Shows that the desertification in the Tibetan Plateau, based on the slow natural desertification process under the dry and windy climate, is a man-made accelerating and aggravating process as a result of the joint effects and mutual activating and promoting of the natural and man-made desertification factors. In the light of climate desiccation and increase of the land pressure resulted by population growth, unless the effective control measures are taken the development of land desertification on the Tibetan Plateau is certain to speed up and to exacerbate.

Key words: Tibetan Plateau, Land desertification

1. General Situation of the Tibetan Plateau

The Xizang(Tibet) Autonomous Region, lying on the main body of the Qinghai-Xizang Plateau, the roof of the world, has a total area of 1,200,000km² with a population of about 2.29 million.The north and west parts of the Tibet are vast expense of cold and highly desiccated highlands. The south part is consisted of the Himalayas and the lakes and basins at its northern foot with the Yarlung Zangbo River running from west to east. The east part is an area formed of a series of high mountains alternating with river vallies. The terrain of the Tibet slopes from northwest to southeast with an elevation of over 5000m. in the northwest to about 4000m. in the middle reaches of the Yarlung Zangbo River.

Temperature and humidity varies with elevation and time of year, the average annual temperature ranging from-3.0℃ to 11.8℃. Most part of the Tibetan Plateau has a long and frigid winter and is dry and cool in summer. The annual mean precipitation varies from 1500-3000mm in the northern foot of the Himalayas to about 400mm in the middle reaches of the Yarlung Zangbo River. The broad north and west parts has rainfall less than 400mm and even less than 50mm with 80—90% being concentrated in summer and autum(May to October).

The Tibetan Plateau is a region where the tibetan nationlity, accouting for 96.39% of the total population, lives in compact communities with a density of 1.86 pepople per sq.km. The Tibet is predominantly a farming and stock-raising region in which north and west parts are dominatedy by stock-raising and the southeast by farming.

2. Types and Distributions of the Desertified Lands.

2.1 Types of the desertified lands Remote sensing and field investigation reveals that there exists following seven kinds of desertified lands on the Tibetan Plateau:

Shifting sandy land refers to the kind of sandy area where vegetation coverage is less than 10% and even uncovered, with clear sand veins on the surface. The shifting sandy land is usually in the forms of flat sandy land, crescent dunes and the dune chains, vertical and horizontal dunes, star dunes, crescent sand ridges and huge compound sand mountains, of those which distributed on mountain slopes, being in varied shapes and high climbing altitude, is a particular aeolian geomorphologic form on the Plateau.

Heavy salinized land is a kind of saline-alkali soil where the degree of mineralization of ground

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water is 10-30 grams per litre, the salinity on the surface is over 30% and there is almost no plants grown on them.

Salt desert refers to the salt ponds that can be used to exploit. Above three kinds of desertified lands belongs to seriously desertified land with a total area of 8365 km^2 on the Plateau.

Semi-fixed sandy land refers to the sandy area where the vegetation coverage is between 10-30% and the sand surface is in unstable state with clear wind eroded marks on the surface.

Uncovered gravel land with vegetation coverage less than 10% and the ground surface being seriously coarsened by wind erosion. These two kinds of desertified lands belongs to medium desertified land with a total area of 111785 km^2 on the Plateau.

Fixed sandy land refers to the sand dunes and flat sandy areas where vegetation coverage is over 30% and the sand surface is in stable state.

Sparcely vegetated gravel land has a clearly seasonal changes in landscape, being in gobi in dry and windy season and in desert steppe or even steppe in warm and moist season with the vegetation coverage 10-30%. These two kinds of desertified land belongs to lightly desertified land with a total area of 84590 km^2 on the Plateau.

2.2 Overall distribution features of the desertified lands On the whole, the desertified lands on the Tibetan Plateau has following distribution features: 1) although widely distributed on the various natural zones of the Plateau, the desertified lands is comparatively concentrated in the wide river vallies, basins and lakesides; 2) desertified lands are mostly alternated with farmlands, grasslands, water bodies and other land forms, being in a scattered and spotted distribution pattern on the plateau surface and in striped and discontinuous distribution in the rives vallies and lakesides; 3) there is a distinct inter-regional differences among the types of desertified lands and the distributions, on the north and west parts of the Tibet, the first place is given to the gravel desertified lands with heavy salinized land and salt desert limited to receded lakes and salt water lakesides, the south part of the Tibet exists both sandy and gravel desertified lands, and only small area of gravel desertified land distributed in east part of the Tibet; 4) from north to south and from west to east, the area of desertified lands on the Tibetan Plateau gradually reduces with the distribution patterns changing from the scattered and spotted to the striped and discontinuous.

3. Contributing Factors of Land Desertification.

3.1 Fragile ecological environment The Tibetan Plateau, with its high elevation and strong continental climate, is the driest and the coldest region compare to the same latitude regiones with the arid and semi-arid areas accounting for more than two thirds of the total area of the Plateau. Being under control of westerlies in winter half of year, annual average wind force is more than 3.0m/s, and for some parts of the Plateau, monthly average wind force is as high as 6.4m/s, and annual strong wind period (wind force $\geqslant 8$) is 100-150 days.

During the uplift of the Plateau in the past 4 million years, a vast amount of lose materials deposited in the basins and vallies of the Plateau. The sediments, owing to the poor cohesion, is susceptible to wind erosion and sandy disertification.

Vast sandy ground surface with sparce vegetation and dry and windy climate provides a basic condition and motive force for land desertification on the Plateau. The fragile ecological environment of the Plateau carries with in itself the factors and slow natural process of land desertification.

3.2 Excessive land use Among the man-made factors of land desertification, the over land utilization caused by population growth is of the first importance. At the beginning of the 1950s,.population of the Xizang Autonomous Region was only 1.15 mollion and it was increased to 2.29 million by the beginning of 1990s. With the populatiom growth, domestic animals increased from 9.74 million to 23.20 million, which formed a huge deficit between the low land providing ability and the tremendous man's producing and living needs, and necessarily led the over exploitation and utilization of the land resources.

4. Developing Trend of Land Desertification

4.1 Trend of natural desertification factors Since the 18th century, the Plateau has been characterized by desiccation trend, dry period being longer and wet period being shorter. Since the 1950s, particularly, there has been continuously decrease in precipitation and incerase in aridity index, which will certainly intensify the already existed desertification process.
Based on the study of the tree growth rings in the past 400 years (Wu Xiangding et al.1980), the Plateau is now in another higher temperature period which may continue to the beginning of the next century.
Wind speed observed in the past 20 years shows that strong wind days is tending to decrease in the Yarlung Zangbo River Basin and to increase in north and west parts of the Plateau.
In brief, at the end of this century and the beginning of next century, land desertification in north and west parts of the Plateau will further expand owing to temperature increase, climate desiccation, cohesiveness of the ground clastic materils reduction, strong wind period and wind erosion intensity increase. Although the slightly increase in precipitation and decrease in strong wind days in the Yarlung Zangbo River Basin, climate may still further desiccate because of the increase of temperature and evapotranspiration.

4.2 Trend of man-made desertification factors Among the man-made desertification factors, increase of population pressure is the source of over land use. Under inertial affect of population growth, the Xizang Autonomous Region will certainly maintain a higher population birthrate and natural growth rate towards the end of this century and the beginning of next century. With population and domestic animal growth, more foods and forage are needed to feed them, which is bound to intensify the over utilization of the land resources, and necessarily leads to the further expand of unreasonable man economic activities characterized by over reclamation and over grazing.
At present, the local farmers and herdsmen rely mainly on firewood and livestock dung as living fuels, limited by technical competence and economic situation, it is impossible to popularize the use of electricity, wind, solar and other energes in broad farming and pastoral areas in the near future. Thus the destruction of the natural vegetation to resolve the living fuels will still exist to a great extent and even worsen.

5. Conclusion

With development of the tibetan economy, the scale and intensity of the land resource exploitation and utilization will unceasingly extend and increase, and the man-made disturbance and destruction of ground surface will increasingly aggravate. Therefore, with climate desiccation and increase of land pressure, unless the effective control measures are taken, the development of land desertification of the Tibetan Plateau is certain to speed up and to be exacerbated.

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The Reasons of Land Desertification and Its Prevention and Control Ways

Rahmutulla Adilla, Alishir Kurban and Adiljan Ibrahim

Abstract- In this paper, mainly discussed the concept and definition of desertification,and described the expressions of desertification.And analyzed the reasons of desertification and proposed the ways of prevention of desertification and amelioration of the desertified land in Xinjiang, China.

Key Words: Desertification, Prevention, Amelioration

1.Introduction

The world has generally realized that the desertification is one of the global environmental problems since The World Desertification Meeting was held in 1977.At present, desertification limitates and threatens the life of people and sustainable development. So how do we prevent desertification and ameliorate the desertified environment is the urgent problems of that humanbeings are confronted with. It is necessary to discuss the concept and definition, the reasons and expressions, the prevention and ameliorating techniques of desertification for resolving the problems.

2.Concept of Desertification

We think the definition of "desertification" refers to destruction and pollution(deterioration)of human environment resulting directly or indirectly from unscientific production activities of humanbeings.

In modern times, the living and production activity of man are closely linked to the natural and social environment. And the two kinds of environment composed the human environment together. There is an inevitable contradiction on the process of utilizing and remaking the environment that is mentioned above. It is a normal phenomenon of unity of opposites between humanbeings and natural world.

If humanbeings carry on producing basis on the objective properties of environment and their developing laws, the human environment will develop to the direction that is beneficial to human and keep the unity with human.Therefore, the human environment becomes better and give birth to "oasisation". On the contrary, if human activities violate the objective developing law of environment, the human environment will develop to the opposite direction and become worse, and then give rise to "desertification".

The main forms of desertification resulting from inconsistency between human activity and natural environment are shown as follows: 1. The destruction of natural environment resulting from irrational developing and utilizing of natural resources; 2.The pollution of environment that is brought by urbanization and development of industry and agriculture. The concrete expression of desertification includes land sandification, salination, drought,barrenazation, lower production, exhausted of resources, changing of water quality, changing of climate resulting from human activity,destruction of environment structure, crowding of housing, insufficient supplement for fuel and material, destruction and pollution of scenic spots,historical relics and historic sites, etc.

Desertification is susceptible to occur in fragile environment, including steppe, subdesert, and desert area with arid and semiarid climate, and it is very serious.It is also occurring in humid forest and meadow. At present, desertification occurs in the developing countries in the arid zone as well as in the developed countries in humid zone. So we can say "desertification" is worldwide "man-made social effects of pollution" or "artificial disaster".

3. Main Expressions of Desertification in Xinjiang

In recent 50 years, developing of industry and agriculture has accelerated the social progress, and large "oasis" has been established in desert area. But desertification also occurred resulting from destruction and pollution of ecological environment. Main expressions of it are:

3.1 Expression of worsening of water resources and environment There are some unfavorable changing water resources which is influenced by developing of land in Xinjiang, and they are described as follows: 1) Most of the rivers shrink at mid and lower reaches, can not flow into their destination; 2) Aggravation of soil erosion cause to rise the silt content of water; 3) Water of rivers and lakes is mineralized and salinized continuously; 4) Natural lakes are shrunk and dried, water level dropped; 5) The amount of irrigation water is increased, underground water level is rose, water quality is reduced in the cropland. The amount of water supply from outside the irrigation area to cropland is reduced, underground water level dropped; 6) Some rivers that flow across urban area and mining area pollinate resulting from industrial and urban waste water.

3.2 Expression of degeneration of vegetation The activities, including opening up undeveloping land, overgrazing of livestock, over cutting of forest and scrub, digging for medicinal materials influence on desertification and give rise to some problems as follows: 1) The lumber forest is decreased in quantity and quality, because of serious cutting of mountain forest; 2) Populus forest, scrub forest and secondary forest at the river valley of plain area are declined and destroyed; 3) Water supply of natural grassland is cutting, productivity is dropping and the area narrowing, because of drought and overgrazing; 4) The number of valuable population is decreased or extinct on the plant community.

3.3 Changing about animals The destruction of animal habitat by men and unrestricted hunting give rise to disadvantageous changing in animal population in Xinjiang . It is characterized as follows: 1) Some populations have already extinct; 2) Some populations have been decreased in number; 3) Distribution area of some populations is reduced; 4) Some livestock become smaller and productivity is decreased.

3.4 Expression of deteriorating of soil environment Destruction of water, vegetation, soil surface resulting from the influence of human activities causes to deterioration of soil. It is mainly expressed on: 1) The area of secondary salinized land and marsh is expanded continuously; 2) Erosion by wind and water of soil is aggravated; 3) The ability of preserve moisture and fertility of soil is declined; 4) Land sandification and hardenization are aggravated; 5) Water and land are contaminated by industrial waste water and pesticides..

3.5 Expression of aggravation of desert Xinjiang is the second largest sand desert region and has rich sand sources. The area of desert had not been so large as it is today 50 years ago. As the influence of human activities, the desert was expanded seriously. The aggravation of desert is expressed as follows: 1) The area of desert was expanded to outside continuously; 2) Fixed dunes were changed into mobile dunes; 3)Sand grains on mobile dunes are flying on the sky and can not scatter easily, as the result, the light and heat absorption of plants were influenced by sand dust.

4. The main reasons of desertification in Xinjiang

4.1 The base of natural resources and environment is fragile Xinjiang is located in the continental closed arid area of middle Asia, territory reaches to $1.66 \times 10^6 km^2$. High mountains and basins are linked together, heat and water are allocated unevenly. Water supply for one year is $24.29 \times 10^{10} m^3$, average precipitation is 150mm. The area of which has higher than 250mm rainfall is about 23% of the total area. The area of which has higher than 150mm but less than 250mm rainfall is about 24%, 75-40mm rainfall area is about 27% and less than 20mm rainfall area is about 26%. There are five climate zones, including frigid zone, subfrigid zone, cold temperate zone, temperate zone and warm temperate zone, and five climate regions, including humid, subhumid, semiarid, arid and super arid region under the control of arid climate. According to these climatic factors, there are formed five natural environmental regions,including forest, forest meadow, steppe, subdesert, desert etc. The area of desert and subdesert is larger than that of other's and is about 31% of the total area of Xinjiang. Steppe is about 9.6% of the total area. The environment region of forming from other vegetation only is about 13.7% of the total area. The area of which has the vegetation coverage less than 1% and barren land is about 45.6% of the total area. There are large sand deserts in the desert and subdesert environmental regions in Xinjiang. For example, the world secondly large mobile desert—Taklimakan Desert and Kurban Tongut Desert, Kumtag Desert etc. The these deserts is about 25.44% of the total territory of Xinjiang. The desert, subdesert and steppe are the main part ol environment in Xinjiang. And it is characterized by simplicity of its structure and fragility of balance of enei materials. Thus the environment is very susceptible to human activity.

4.2 Growing of population is fast, carrying capacity of environment is low Generally recognized that the carrying capacity of man or livestock in arid zone is 7 men/km^2 or 20 livestock/km^2. At present, the ratio is 11 men 24 livestock/km^2, and has already over the critical carrying capacity. The pressure for natural resources and envir is strengthened, because of population growing fast. Poor fertility and low productivity of soil cause to expand th opening undeveloped land. Expand of opening undeveloped land give rise to shortage of water resources, thus, th that are distributed at mid and lower reaches of river, and the lakes can not get enough water and speed up desertif Because of insufficient supply of fuel, the people have to cut forest for firewood. As the result of these reasons, a of serious problems appear in desertification including erosion by wind and water, salination, developing to activate of sand, decrease the biodiversity, "barrenize" of resources and environment etc.

The essential reasons among the problems of causing desertification in Xinjiang can be summarized as foll Growth rate of population is higher than carrying capacity of environment; 2) Fuel supply is insufficient for living; fertility and productivity is low; 4)Irrational developing and utilizing of land; 5) Irrational exploiting of water resou Irrational disposing of three kinds of wastes from industry and agriculture; 7) Backward in science and technolo the poverty.

5. The Ways of Prevention of Desertification

The people lived in Xinjiang have made untiring efforts to fight against desertification for long time. Esp they have adopted some vigorous measures. These measures can be concluded as follows: 1) Developed fa shelter-forest; 2) Constructed forest belt for fixing sand and avoiding from wind; 3) Built firewood forest; 4)I natural vegetation by flood; 5) Blockaded natural vegetation around sand dunes; 6) Set up some water constructi Developed and exploited mineral resources for fuel; 8)Developed inorganic fertilizer and utilized plastic film; 9) on the work of subdividing and planning of land; 10) Published some laws, including grassland law, law of forest law, law of water resources and environment.

These measures take effect quietly on controlling desertification in Xinjiang. But to solve the seven essential that are causing to desertification completely, these measures are not effective enough on keeping off desertif intensity and scale that are growing continuously. From the point of view, we propose seven special ways for pre desertification as follows: 1) Population must be suited to the carrying capacity of land; 2) To exploit and utiliz energy, marsh gas and wind energy; 3) To develop effective and economical irrigation techniques; 4) To grassland agriculture or ecological agriculture; 5) To use biological subproducts completely and renewably; 6) arrangement of land really; 7) To implement national and international laws of resources and environment seriou strictly.

For ameliorating the environment which have already been desertified, these measures are effective as foll To carry ecological analyzing and look for essential problems, and solve them properly; 2) To divide des environment, protect ecotone first, and then stabilizing oasis; 3) To plant deep rooted plants and xerophyte, in *Alhagi sp.* and *Colligonum sp.* where the land with underground water supply; 4) To introduce, breed or culture o peculiar or appropriate species(including animals, plants, and microorganisms) which are reduced in number or 5) To ameliorate desertified environment by applying ecological techniques accordance with the base of eco principles.

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Assessment and Mapping of the Desertification.

Lyuba KAPUSTINA*

Abstract- The current state of desertification on the pastures of South Kyzylkum (Uzbekistan) was aleady estimated during geobotanic investigation in the 1990-1996 years. This data were completed by aerial and cosmic photographs and topographical maps. Then "Map of Current Desertification" (scale is 1:300 000) was drawn for this territory. The types and the classes of desertification are shown at this map.

Key Words: desertification, desert, degrading vegetation, wind erosion.

1. Introduction

The region of our investigation belongs to the Turanian Province of Iran-Turanian Subdistrict of Sakhara-Gobi Desert Zone. Natural vegetation of the Uzbekistan is 27 million hectares dominated by year round natural pastures, wilt 96% of pastures are in the desert zone. Population is 21,9 million. Livestock of sheep are 38,6 million and wilt 138 sheep for each 100 hectares agricultural land. Intensive human activity and utilization of natural resources often bring about the disturbance of the ecological equilibrium which triggers desertification processes. These are the reasons of the degradation of the vegetation and soils of Uzbekistan.

2. Classification of desertification processes of South Kyzylkum.

Desertification processes on the 1476600 hectares of South Kyzylkum desert were studied by methods of geobotanic investigation , lage-scale mapping and analysis of " Vegetation maps" which were drawn in the preceding years.

The " Map of Current Desertification of South Kyzylkym" was mainly based on criteria worked out by specialists of the Institute of Desert Research (Kharin et all, 1988). However we additionally estimated the grade and the area of degraded vegetation growing on different soils when we determined the types of desertification. This is very important for a correct elucidation of the dynamics of desertification and for pastures improvement.

Our investigations enabled us to differentiate between five desertification types:

2.1. Desertification by degrading vegetation, which shows four variants: (Table 1)

On loamy soils the degraded vegetation is 179207 hectares.

On shallow loamy soils of eroded mountains and hilly premountains the most important factors of degraded vegetation are overgrazing and clearing of Salsola arbuscula and Artemisia turanica. Under slowly ongoing desertification of hemipetrophytic (dominated by annual halophytes like Climacoptera lanata, Gamanthus gamocarpus, Girgensohnia oppositiflora, G. diptera on tops and slopes of chalky deposits, and by Salsola arbusculiformis, Artemisia turanica and A. diffusa in depressions) and petrophytic variants of plant associations (Salsola arbusculiformis, Artemisia turanica) ruderal species like Peganum harmala and Ceratocarpus utricolosus intrude.

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On loamy soils of premountainous plains the main factors of degraded vegetation are avergrazing and clearing Artemisia diffusa and Salsola orientalis. The succession changes according to the pelitophytic row wich probably starts with a society of Artemisia diffusa , S. orientalis, Carex physodes and Poa bulbosa, into which initiatially Peganum harmala intrudes (weak desertification). Later a strong desertification is characterized by societies dominated by Peganum harmala and Artemisia diffusa or Peganum harmala alone. On the rather sandy grey-brown soils the vegetation is degraded on 337323 hectares caused by overgrazing and clearing of Artemisia diffusa, Convolvulus hamadae, Astragalus villosissimus, Salsola arbuscula and Haloxylon aphyllum. Trees and shrubs are using for fuels. 7000 half-shrubs are cut for waving silkworm (Bombyx mori) cocoons per year. Here the desertification starts with psammophytic societes intruded by Eremopyrum orientale, E .distans, Vexibia pachycarpa and Peganum harmala. In the last stage of anthropic successions, societies of Arthratherum pennata, Iris songorica, Peganum harmala and Eremopyrum orientale are dominating in smaller, degraded, sandy places.

On desert sands the degraded vegetation comprises 283359 hectares. A low degree of desertification is most often characterised by the introduced weeds Arthratherum pennata, Ammothamnus lechmannii and Peganum harmala in psammophytic societies which are dominating Haloxylon persicum, Calligonum setosum, C. ellatum, Carex physodes, Artemisia diffusa, Salsola arbuscula and Astragalus paucijgus. In places with strong desertification on less hardened, furrowed, and lacunose sands as well as sand plains societies of dispersed Ammodendron conollyi, Arthratherum pennata, A. karelinii, Ammothamnus lehmanii, with Agriophylum pungens, Peganum harmala and Eremopyrum orientale are dominating.

Tabl 1. Degree and scale of the desertification (hectares)

Class of the desertification	Types of the desertification: Degradation of vegetation – grey-brown soils – loam	sandified	desert sand soil	solanisation of soil	water erosion	wind erosion	tecnogenic desertification	Forest planting
Slight	88197	78223	172403	52413	43960	332468	2960	
Moderate	53860	60600	62370	23470	7090	169313	6590	14800
Severe	37150	198500	48586	19290	19180	268236	4099	
In all	179207	337323	283359	95173	70230	770017	13649	14800

2.2 Desertification caused by wind erosion.

770017 hectares are affected by wind erosion. There is close correlation between the two types of desertification caused by degrading vegetation and by wind. The more the vegetation is destroed the more hearthes of deflation arise. The wind erosion leads to a reduced the thickness of the loamy soils and uncovers the gypsum layer. There are dominating annual halophytes like Ceratocarpus utricolosus , Girgensohnia oppositiflora and G. diptera on degraded loamy soils. Deflation of the desert sands and sandy gray-brown soils is causing sand dunes. More then 50% this area belong to strongly desertificated places around settlements and water wells.

2.3. Desertification caused by water erosion.

70230 hectares are undergoing by water erosion.

On hilly premountains and slopes of the desert mountains dominate sediments which can easily be washed out. They underline water erosion also if precipitation is low. Such types of desertification correlates with desertification caused by wind erosion and degradation of hemipetrophytic and petrophytic variants of the plants societies of the Kuldzhuktau and Kokchatay mountains and their hilly premountains.

Desertification caused by water erosion is visible too on the dry waterway of the old rivers which to fills up water in spring time only.

2.4. Soil salanisation. caused by artificial lake Shorkyl and water and wind erosions is on the 95173 hectares.

3. Conclusion

The given analysis of desertification processes on the territory of the South Kyzylkym detected 54% of degraded vegetation (23% is on the sandy grey-brown soils, 19% is on desert sands and 12% is loamy soils). Wind erosion causes aeolic accumulative processes on the 52% of territory, water erosion is 5%, soil salanisation- 6% and machine- caused desert cover- 1%. Man-made reservoirs are reason for salanisation of solis and degradation of vegetation on 19560 hectares. Cutting of the half-shrubs for silkworm cocoons is the reason for degradation of vegetation and wind erosion on the 38380 hectares.

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On the Regional Problem of Desertification in Central Asia

Kh.T. TURSUNOV

Abstract - The study on the desertification in Central Asia is of both theoretical and applied importance. Ecological crisis is unfolding now in Central Asia due to the drying up of the Aral Sea and a dramatic growth in the anthropogenic pressure on the environment which will have adverse socio-ecological and economie consequences for the whole world. This paper deals with the major causes and conseguences of desertification in Central Asia and determines the main lines in the desertification control at a regional scale.

Key words: desertification, ecosystem, degradation, convention, strategy.

1. Introduction.

The UN convention on the control of desertification exspresses concern in connection with the effect of desertification and drought on Central Asian states. Central Asian region comprises such sovereign states as Uzbekistan (447,4 thousand sg. km.); Turkmenistan (488,1 thousand sg. km.); over Tadjikistan (143,1 thousand sg. km.); Kyrghyzstan (198,5 thousand sg. km.) and the south of Kazakhstan. Mountains occupy 32,3% of the Central Asian territory, the rest is occupied by deserts, semideserts, steppes and montane valleys. The population of Central Asia is over 50 million and it may grow twice as high by 2020 if the current population growth is maintained. A high anthropogenic pressure on all the components of environment for a long time and drying up of the Aral sea have resulted in a dramatic deterioration of the ecological situation, the growth in the diseases and mortality of the population in the region. Further deterioration of the environment, appearance of the local and regional crisis situations and degradation of the ecosystems may become a main limiting factor of the sustainable development of the states in the region on the threshold of the 21st century, which may have global socio-economic consequences.

2. Major causes, scale and consequences of the desertification in Central Asia

In scientific literature and official documents desertification is characterized as the last stage of a slow degradation of environment in arid zones resulting from a complex interrelation between the socio-economic system (poverty, diseases, economic and social instability) and the natural-anthropogenic factors (drought, misuse of soil, water and plant resources, technogenic processes, etc). There factors, as a rule, contribute to the development of one another, thus causing desertification (Babaev, 1994).

In Central Asia, irrigated agriculture has developed for more than 6 thousand years. In such a long period of time, both natural and anthropogenic desertification has developed under the arid climatic conditions. An aggravation in the processes of ecosystem degradation has been observed since 1950-60s. The major causes of this aggravation are as follows: (1) a long-term and lop-sided extensive development of the industries of the region and monoculture of cotton; (2) specialisation of the agriculture in mainly water-consuming crops; (3) overgrazing, undergrazing, deflation, erosion, salinization; (4) development and mining of useful minerals; (5) the growth in the transport, industrial and agricultural loads; (6) construction of roads, pipes and cities; (7) low concern of the local population in controlling the desertification; (8) no financial support of developed countries in resolving this problem, and other causes. The studies show that the factors resulting from the human activity dominate; therefore desertification in terms of genetics is of the anthropogenic nature.

An intensive expansion of the area of irrigated lands in Central Asia has resulted in the drying up of the Aral Sea. The area of the sea has decreased from 66,1 thousand sq.km in 1960 to 32 thousand sq.km in 1996, the volume in the same period of time has dropped from 1064 cubic km to 285 cubic km. So, another peculiar desert has appeared on the map of Central Asia - sandy-solonchak desert Aral, the area of which is about 4 million ha due to the shrinking of the Aral Sea. In future, once the sea has completely dried up, precise natural borders of the new desert will appear to form, whose area will be over 5,65 million ha. This desert will be mainly of sandy-sors type with small bitter-salty lakes (Khabibullaev, Rafikov, 1994). In this connection, there is a danger of junction of this new desert with the great deserts Karakum and Kyzylkum, and Ustyurt, and of the formation of a single desert region in Central Asia, similar to the Desert Sahara. The equilibrium of biosphere has been disturbed at a regional scale, that affects adversely the development of Central Asia. The ecological situation in the Aral region got practically out of control and keeps on aggravating. Phytomelioration and other steps do not yield desirable results and the eolian matter (15-70 million tonnes/year) is wind-borne from the desert.

The ecological crisis in Central Asia is expressed not only in the consequences of the Aral Sea drying, but also in the drop in the soil fertility, shalowing of water sources, descrease in the amount of woodland, degradation of the montane and desert pastures, immense polution of the soil, waters, air, ets. Flora and fauna are now vanishing with a threatening speed. In Central Asia, the development of agriculture and industry have always been accompanied by adequate nature-protecting measures. Now, due to the transition of Central Asian states to market relations, mining of useful minerals has significantly increased followed by the degradation of deserts, oasis, and mountain ecosystems, and heavy contamination environments. Only in Uzbekistan over 100 million tonnes of the wastes are formed in the mining industry in a year, occupying the area of 10 thousand ha. In the Kyzylkum, the development of 40 new gold deposits is under way, which may inflict heavy damage to the nature of the desert. Noteworthy, measures to control further desertification have not produced any positive results.

3. The strategy of desertification control in Central Asia

The strategy of desertification control at both regional of world-wide scale is expressed in the UN convention on the control of desertification adopted in Paris in 1994 and coming into effect in 1997.

It is noteworthy that every country, based on this Convention, should develop its own strategy of the desertification control taking into consideration its own ecological and socio-economic priorities. Due to a peculiar geographical situation and other natural factors, it is necessary to co-ordinate national strategies of desertification control in Central Asia. Persuing their own interests in using natural resources, Central Asian states cannot but follow a known concept that Nature knows no borders and everything in it is interconnected. The countries of the region should perform their activities on nature management in accordance with the principle expressed in "Agenda for 21st century" adopted by UN.

The following, in our opinion, should be the priority in controlling desertification in Central Asia: (1) preventing of the further drying up of the Aral Sea, fixing of the exposed bottom of the sea; (2) improvement of the monitoring and zoning of territory Central Asia to assess the modern state and to forecast further desertification; (3) introduction of new resource-saving technologies current knowledge, know-how, ets. (4) optimization of pasture use; (5) activization of the participation of the local population in controlling desertification; (6) attraction of the funds of developed states for the effective solution of the desertification problem in the region, ets.

4. Conclusion

Currently, desertification in Central Asia is developing and solution of this problem and its prevention in time are important prerequisites for ustainable development of Central Asian states in the 21st century.

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UN Convention on the Control of Desertification.

New Technologies for Sustainable Production in Arid Areas

Keynote Address

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New Technologies For Sustainable Production In Arid Areas

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1. Introduction

The arid areas of the globe support a significant proportion of the world's population and have done for many thousands of years. Walker (1995) suggested that pastoral use of the arid lands (rangelands) is considerably older than 5000 years and is the oldest form of agricultural land use.

During those 5000 years, the world's arid lands have produced many innovations and technologies that have provided the impetus for significant social and economic development. In particular, technologies for water harvesting and distribution enabled water to be captured from rivers, overland flow and underground sources for the enhancement of grazing and for the irrigated production of crops. Ghanets, the horizontal interception wells in Iran that stretch over many kilometres, are thousands of years old and integrate sophisticated engineering and hydrogeology to harvest water for communities and agriculture. In addition, technologies for water conservation and for increasing water use efficiency have provided the basis for cropping in very low rainfall situations. The rock mulched gardens of NW China are very old and are excellent examples of ancient technologies that have survived to the present day.

Across the arid regions a range of technologies were developed to replenish seed stocks, regenerate pastures and manage livestock. Some of these, such as the attachment of seed bags to the hooves of pack animals, were quite ingenious and demonstrated a high level of understanding of the need to and the processes for sustaining the arid pastoral lands.

In addition, a wide range of technologies have been developed to meet the needs of those living in arid areas and to enhance their socio-economic situation. These are perhaps too numerous to dwell on here, but would include innovation in transport, communication, dwelling construction, use of metals and, not the least, weapons.

The current state of much of the world's arid lands would, however, suggest that this long history of technological development has not resulted in sustainable land use. Indeed, there is evidence that over the last few hundred years, there has been a loss in the ability or capacity to apply some of this historic technology, which would suggest that it may be that the social or economic aspects of these practices that were not sustainable. Whatever, the cause, it is clear that habitation in the arid lands in many parts of the world has not been able to achieve sustainable use of the resources. Indeed, the parts of the world's arid lands where economic and social development is occurring today are generally those areas that have had access to a resource outside the traditional soil and vegetation resource used to sustain social and economic development in the past. While access to these 'new' resources has provided significant economic impetus, the sustainability of use of these resources is of course questionable in the long term. While activities, such as the extraction of minerals, particularly oil and extraction of underground water resources at rates above recharge have provided significant development they may only be able to sustain development for a short period in historical terms. In this sense the result may not be different from that of past technologies applied in the arid lands.

To some extent, the commercial pastoralism of the developed world is quite distinct from the subsistence grazing of the developing world. Large scale commercial pastoralism land use is relatively new in most areas of the world, being less than 200 years old. However, arid areas in the developed world are exhibiting many characteristics that would suggest that sustainability of the pastoralism enterprises is at best uncertain, and in a number of cases, often not achievable. There is certainly an international challenge to improve the sustainability of use of the world's arid lands.

The question for this paper is what can technology contribute to sustainable habitation of the arid regions? This must be explored against a background of very significant technological development, but limited access to this technology by dwellers of arid lands. This access is limited by remoteness, economic capacity and the general low productivity of arid areas.

2. Sustainability

It is important to ensure that we are working from the same understanding, or indeed challenge of sustainability. Sustainability, in summary, is the use of the resources in a manner that ensures maintenance or enhancement of the environment and ecological systems, while providing for ongoing social and economic development. It is not a constant state, but varies over time and space, evolving with the ethics and objectives of the community. (Robertson 1996)

Critical to all sustainability issues in arid areas, is their natural biological productivity which is very low and variable. In Western Australia production in the arid areas depends upon the land system and the season.

In the best seasons, saltbush (Atriplex sps) pastures can produce up to 1 tonne of dry matter per hectare, while Mulga and Wanderrie (perennial grass) pastures may produce as little as 110 kg dm/ha in the same 'best' seasons. The difference between best and worst seasons also can be dramatic, with production of 800 - 1000 kg dm/ha in a 'best' season being reduced from nil to 100 kg dm/ha in a worst season. (D.G. Wilcox, 1997, pers. comm.)

The ecologically sustainable use of this resource will depend upon the annual production which in turn depends upon land system and rainfall. Each ecosystem has a limit on safe use each season which cannot be exceeded without degrading the pastures and detracting from future productive capacity. This figure is generally considered to range from 15% to 25% of total biomass produced. Hence, in a biological and importantly, an economic sense, the sustainable level of use of arid lands is very low and in many years may be nil. Unless individuals have access to large areas of this resource, sustainable economical or social development will be difficult to achieve. As a consequence, pressures to enhance economic or social outcomes have resulted in most of the world's rangelands being used at significantly above levels compatible with sustainable use from an ecological perspective.

This inevitable conclusion has been recognised by most countries of the world in their agreement to the International Convention to Combat Desertification. This Convention (United Nations 1994), in understated language, recognises that "despite efforts in the past, progress in combating desertification and mitigating the effects of drought has not met expectations and that a new and more effective approach is needed at all levels within the framework of sustainable development".

It is more difficult to generalise with respect to a judgment as to whether social and economic sustainability is being met through current use of arid lands, as the definition of desired standards and rates of social and economic development varies greatly, particularly as one moves from subsistence agriculture to commercial pastoralism.

In considering the issue, there are some assumptions that are widely accepted. For example, most governments and communities expect economic and social conditions to improve over time, and indeed, there are few economies where economic growth is not positive and regular, Social development is a less easily defined progression, but in general terms the aspiration is to enhance the social condition. Clearly for this to be achieved in the arid areas, where the basic economic opportunities are driven by the nature of the land resource and its limited production capacity, is at least a challenging task. Unless the population, the number of families or number of businesses declines consistently over time so that individual unit access to the resource is enhanced, it is not possible to develop on a per capita basis, economically or socially, unless technology is able to increase the productivity of the resource base or an alternative or 'new' resource becomes available. The corollary is also true, more families, more people, or more businesses on a finite resource will result in reduced economic and social benefits per unit. The latter appears unfortunately to be a common situation in arid lands. If this dilution effect is compounded by an actual decline in resource condition and productivity, this decline in social and economic conditions is likely to be more rapid. Unfortunately, this is also a characteristic not uncommon in arid lands.

Habitation in much of the world's arid areas is not sustainable unless:

a) Productivity of the natural resource can be increased.
b) There is the opportunity to identify and develop additional resources, not traditionally used.

Non traditional resources can include

minerals
water
tourists
solar energy
wind

In an international context, a number of these alternative resources are available across arid areas. The challenge is to develop and apply appropriate technologies so that they can contribute to the sustained use of the arid lands.

3. Technology To Enhance Sustainability

Technological development is continuing to progress at an exponential rate as we approach the new century. At least theoretically, the world's technology is available for the arid lands. However, actual application of new technology to arid lands is limited for a number of reasons, including

mismatch between technology and needs
remoteness and isolation
high cost relative to benefits
lack of access to capital
lack of training/skills

While there might appear to be a vast difference between a developed country's commercial pastoralism, such as that practised here in Western Australia, and a subsistence agriculture in North Africa or the Middle East, the difference is one of degree, not nature. Arid areas are by definition of lower biological productivity than the rest of the globe, and in the market driven world in which we live, investment is usually attracted to areas of higher productivity. Both subsistence and commercial pastoralism in arid areas are at a natural disadvantage in this regard.

The low economic returns from traditional uses of arid lands has not all been negative in terms of technology, and in some cases this has been a driving force for innovation. For example, the challenges of managing an intensive and low value resource has led to the development of tools for remote sensing, animal control and communications.

The technologies available to improve sustainability of use of the arid lands can be grouped into 4 categories.

1. Understanding and managing the natural ecosystem.
2. Improving productivity of the resource and the grazing animals.
3. Supporting community and business development.
4. Identifying and developing new opportunities for arid land communities.

4. Understanding And Managing The Natural Resource

There has been very significant progress in the last decade in understanding the ecosystem of arid lands and how management could or should respond. Implicit in managing in a dry and variable environment is the need to understand and respond to this ever present variation. An ability to predict future variation provides an enhanced lead time to plan a response to the variation and hence the capacity to manage better. In this context, perhaps the major advance of the last few years has been the increased understanding of the factors that affect climate. This has resulted, at least in Australia, in an enhanced capacity to provide seasonal forecasts to pastoralists and farmers. These forecasts in turn will become critical to managing risk and variation in arid areas.

Under the National Climate Variability Program begun in 1992, significant progress has been made in understanding the impact of El Nino - Southern Oscillation index, sea surface temperatures and ocean and atmospheric circulation on the climate in Australia. The understanding of these links has improved the accuracy of medium to long-term weather predictions and a range of business support systems have been developed to assist pastoralists use this knowledge to better manage their resources. The National Drought Alert System (Brook 1996) links actual rainfall, seasonal scenarios, pasture cover, pasture growth models and remote sensing monitoring to provide information on range condition and available and predicted feed on a regional and individual property basis.

The use of remote sensing has enabled scientists to monitor the condition of arid lands and through application of models, predict the future condition of the range resource.

The Survey of the nature and condition of range resources is critical to sustainable management and many surveys of arid land resources and their condition have been carried out across the world. In Western Australia, field based surveys are of one million square kilometres of arid land used for grazing is close to completion (Pringle and Payne 1997).

In carrying out these surveys and managing the information, new technologies such as remote sensing, automatic fixing of location using global positioning systems and geographic information systems (GIS) are now all routine practice. In particular, the use of GIS is a great advance as interrogations of data can provide interpretations of data suitable for use in discussing and interacting with rangeland communities. This approach can be very useful in areas where detailed cadastra is limited or non constant.

The process of arid land survey is continuing world wide. A team from Western Australia is currently in Kuwait carrying out a national land evaluation survey. A regional planning project was recently completed in Iran to develop new approaches for national, regional and local planning. In both these cases, the latest technology is being applied to achieve a cost effective and relevant resource inventory, one that will be accessible to users and managers. Indeed, this latter point is critical. Much very useful resource information on the world's arid lands is in libraries or archives and rangeland users are totally unaware of its existence or its implications.

Technologies such as remote sensing have allowed vegetation condition and response to be monitored in near real time (eg Smith 1994). However, generally, the accessibility or usefulness of this information to the land manager has been very limited. Burnside and Smith (1997), have developed a range of products and technologies based on NOAA satellite images and interacted with rangeland managers and administrators to ensure user friendly and relevant information is available. The information has been widely used in monitoring variations in seasonal and grazing impacts.

Indeed, in a general sense, we probably now have the expertise and the tools to design land use systems for most of the arid areas of the world, that would, if they were to be applied, result in sustainable land use. We are also in a position technically to monitor land condition and trends in near real time.

5. Improving Productivity Of The Resource And Grazing Animals

There are a wide range of technologies available to improve the productivity of the resource and the animals grazing them. The technology for rehabilitating rangelands has progressed significantly over the years and the principles are well understood. Machinery developments have resulted in techniques to sculpt or shape the soil surface to harvest water and to apply appropriate mulches to anchor seed, conserve moisture or modify temperatures. In Western Australia large scale regeneration programs have been carried out on the Ord and Fitzroy River Basins in the North West and most property owners have carried out some regeneration on their properties. Many companies throughout Western Australia are routinely rehabilitating minesites, often in very arid and inhospitable situations. In the main, this rehabilitation work has been very successful. A number of papers in this conference add to this already substantial knowledge and have provided solutions to specific and difficult situations.

The challenge is often not the re-establishment of plants, but the long-term protection of areas from grazing. In Australia, this is often protection from feral animals such as goats and donkeys and in some cases native animals such as kangaroos. Elsewhere the problems of land tenure, common grazing rights and nomadic grazing make sustained regeneration difficult. My agency has been involved with several projects in the Middle East where there was resounding technical success, but the regeneration scarcely outlived the project. Indeed, I recall visiting one project in Iran where the critical technology for success was a guard with a 303 rifle.

The nutrition of grazing animals in arid areas is also now well understood. Unfortunately, the provision of feed supplements to animals depastured on the arid land pastures has in many areas increased grazing pressure and further degraded pastures.

Testing regimes and vaccination programs have also had significant impacts on the impact of diseases on animal performance and the safety of the animal products. In Australia, a successful national program/eradication program is on track to achieve an

Australia-wide declaration of freedom from bovine TB by December 31 1997. (Anon 1997.)

Other technologies being applied to improve livestock management, include:

electronic ear tags can be used to control grazing

electric fencing has evolved to include warning devices to signal electric fence and water mill failures

solar power can provide energy for electric fencing

reverse osmosis systems can cheaply desalinate water

6. Community and Business Support

Technology has had a major impact on transport, be it road, rail, sea or air. In the developed countries, this technology is accessed by managers in arid pastoral areas. Planes are used for travelling the long distances involved, and planes and helicopters are used singly or together to locate and muster livestock. In Australia, large road transport 'road trains' are used to move livestock from remote areas to the markets, which are generally on the coast. In addition, modern shipping moves the livestock to remote markets, as far away as Egypt. However, transport infrastructure in most of the arid lands is inadequate and lags significantly behind that provided in more productive and populated areas. Significant investment is required to bring these areas up to a level that provides basic transport needs for communities.

The computer revolution over the last decade has significantly enhanced the capacity to access knowledge, information systems and services. While there are technological gains in the ability to provide access to this information by people in remote locations, the commercial realities of this technology, is that it is very expensive to provide in areas of low population or usage. Hence, while low altitude stationary satellites can theoretically provide access for those in the arid areas of Western Australia to the world's best communication and information systems, the reality is that if these services are supplied by commercial providers, they are not likely to be available in the foreseeable future. Traditional land telephone lines are usually of inadequate capacity to access the technology, and the optic fibre network, like low altitude satellites, are not likely to be made available by commercial providers. Microwave and other radio communication links are options, but they can also be expensive and, in some cases, inadequate.

Much of the world's arid lands are rich in energy, particularly those areas where arid lands coincide with a significant proportion of the world's oil reserves. However, in areas outside these, fuel is a significantly limiting factor to the socio-economic development of arid pastoral land dwellers. This scarcity of fuel results in significant additional pressure on the biological and land resources. The main fuel source is the natural vegetation, already under pressure from overgrazing.

A range of technologies are accessible to address this issue. Research has shown that fuel wood can be grown in low rainfall areas and the technology for establishment and production in low rainfall environments has advanced greatly. Appropriate species, water harvesting and protection are all important components.

New technologies in liquefied petroleum gas and cooking and heating systems are also of potential in dealing with fuel shortages in arid areas. Indeed, it is a real anomaly that arid land communities in some parts of the world are over exploiting vegetation for fuel, while their country may be a major fuel export.

By their nature, most arid areas of the world have high solar inputs compared to the more humid areas of the globe. Hence there is significant opportunity to relieve pressure on the vegetation resources by investment in appropriate solar technology. Recent advances in Australia have significantly reduced the cost of solar cells, and there is now a real opportunity that this technology can become affordable to those in the rangelands. This technology can provide heating, power water pumps and provide energy for cooking.

Some arid areas are well placed to take advantage also of wind power generation. Indeed, wind and solar power can provide adequate power for a small community. Esperance, a town to the south of here, produces 16% of its total power needs from wind generators. Again, the limitations are in the main not the technology, but the ability of our arid land dwellers to access the technology.

Technological innovation in the provision of health services to the world's population has been dramatic, with major technological breakthroughs occurring almost on a daily basis. These technologies again are increasingly more available to urban dwellers, often to the rich urban dwellers rather than to population generally. Those in arid pastoral areas tend to not be able to access these services because of remoteness or lack of capacity to pay for them. A major challenge is to provide enhanced health services and appropriate technologies for arid pastoral lands.

The world is increasingly a global market and in order to get access to funds to invest in further development, communities need to be able to trade products made or grown locally. Technology for understanding global demand and specific market requirements for products, is at a very high level, however, to be a player in this information world, access to adequate telecommunication systems is required. Again, unfortunately, much of the arid world is locked out.

7. Identifying And Developing New Opportunities For Arid Land Communities

Development of alternative opportunities for dwellers of the world's arid pastoral lands is a critical issue. Where the socio-economic development of people living in these areas is limited by the annual production capacity of the land, the living standards of arid land dwellers will continue to decline, unless there is a dramatic increase in the value of livestock products, or they have access to alternative resources.

In Australia, the National Rangeland Strategy has been addressing options for arid pastoral regions. Options include management for nature conservation, mining enterprises, aboriginal land uses, eco tourism and, where water resources are adequate, limited agricultural production.

By far the largest new opportunity for arid land dwellers in Australia and internationally, has been the minerals and petroleum industries. New exploration techniques such as airborne geophysics has greatly advanced the search for new prospective areas. Some of these technologies, for example airborne electromagnetics, have also been used to identify potential potable water supplies in arid Pakistan.

Tourism, eco tourism and management of arid lands for conservation purposes are all new concepts, but potentially can be very important land uses.

8. The Way Forward

The challenge facing the arid lands of the world and the scientists that are working within them is not the ability of technology to contribute to sustainable development.. This is undoubted. Rather, the challenge is how to take technology that is available in one part of the world and ensure that it is appropriately modified or integrated into local environment and land use systems.

Technology needs to be relevant to the users. Often, the technical solution is developed without due regard for the socio-economic situation of the communities. Mechanised land rehabilitation is often unsustainable in traditional grazing communities. Simple things, like trying to replace use of fuel wood by kerosene without understanding the impacts of this on the traditional char grilling of meat.

Overcoming remoteness and isolation is not easy. Governments, national and internationally, have a role in providing infrastructure. However, scientists also have a role in ensuring new technologies are robust and do not require regular sophisticated servicing.

Cost considerations are important. Income in arid areas is low and technology cannot demand large capital investment if it is to be relevant. Low cost technology is critical.

Access to capital is also important if technology is to be applied. Most of the world's arid dwellers have little capacity to access capital. Even in Australia, a country of considerable capital assets, arid land users have found great difficulty attracting finance for investment.

Finally, training and skill development is critical to the transfer of technology and often the level of investment in this area needs to be higher than the investment in the development of the technology.

9. Summary

Scientists working in the arid lands of the world have done a remarkable job in understanding the nature of the resource and developing appropriate technologies for sustainable management within those rangelands. Unfortunately, the application of this technology is not well able to be applied in the arid areas. The challenge for scientists as we move into the next millennium, is to ensure that we can provide technologies that are within the aspirations and capacity of the most important people in the arid lands. That is, those people that dwell in them.

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New Technologies for Sustainable Production in Arid Areas

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Groundwater from Australian deserts

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Abstract - In spite of climatic constraints, desert environments may contain large groundwater resources. Australian deserts mainly coincide with areas of sand dunes reworked from underlying sedimentary rocks which form extensive aquifer systems. Groundwater recharge is actually enhanced by sandy soil and sparse vegetation, and the periodic passage of cyclones compensates for the low annual average rainfall. Sustainability may depend on utilising groundwater storage which has accumulated over hundreds of thousands of years.

Key Words: Groundwater, Deserts, Sedimentary Basins, Fossil Groundwater

1. Introduction

Australian deserts are characterised by sparsely vegetated dunes which reflect underlying sources of sand from extensive sandstone formations. These sandstones are major aquifers and contain large groundwater resources. In spite of the high rainfall deficiency, and insufficient rainfall to generate surface runoff, the sandy soil and infrequent cyclones are often favourable for groundwater recharge.

Deserts occupy much of the centre of the continent within the 3m annual rainfall deficit zone (Fig. 1), and unlike climatically similar areas within this zone, it is the vegetation which is a constraint on pastoral development. Groundwater supplies could be developed throughout much of the desert regions, and one of the major deserts, the Great Sandy, is traversed by a stock route along which some fifty-two shallow wells were sunk. The sedimentary basins below desert regions (Fig. 2) contain larger groundwater resources than adjacent areas of fractured rock aquifers.

The scope of this paper is to examine the coincidence of desert with sedimentary basins in the Australian arid zone and discuss the sustainability of their groundwater resources.

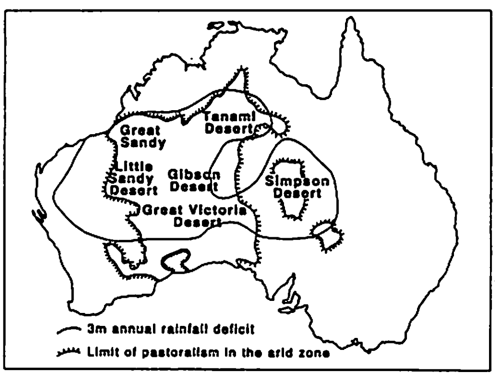

Fig. 1: Major Australian deserts

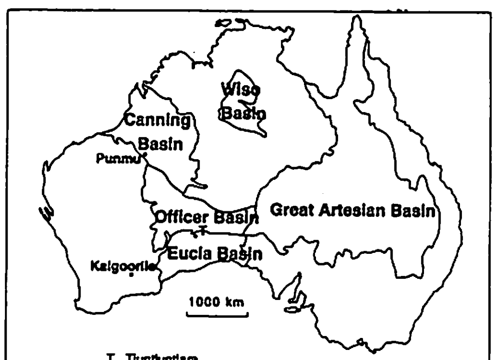

Fig. 2: Groundwater basins

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2. Hydrogeology

Australian deserts coincide with areas of sand and sand dunes reworked from underlying sedimentary rocks (Fig.1), which in most cases are porous sandstones containing large groundwater resources. The Great Sandy, Gibson, and Great Victoria Deserts are developed over the Canning and Officer Basins which contain sandstone aquifers of Cretaceous, Permian and Lower Palaeozoic age (Allen, 1991; Laws, 1991). Groundwater in these aquifers is essentially unconfined and mostly fresh, although throughout much of the area the water table is deep and unrelated to the topography (Commander, 1989).

The Simpson Desert overlies part of the Great Artesian Basin in which there is a confined aquifer of Jurassic age, containing fresh groundwater (Habermehl, 1980; Lau et al., 1987). The structure allows groundwater to be transported under the desert large distances from wetter recharge areas as far away as the Great Dividing Range in Queensland (Habermehl, 1980).

Smaller areas of desert in the Little Sandy and Tanami Deserts overlie areas of fractured sandstones which are not regional aquifers; groundwater availability in these areas is similar to adjacent areas of fractured rocks, in which groundwater resources are small and of high salinity. Tertiary palaeochannel sediments below river beds in the Little Sandy Desert also contain saline groundwater.

3. Groundwater recharge

Groundwater systems in the desert collect short duration runoff and store water underground away from evaporation. Sandy soil and topography which can concentrate runoff, combined with the existence of suitable aquifers, favour the accumulation of groundwater resources. Total rainfall is less important than the intensity and duration. Although the interior of Australia has low annual rainfall, and high rainfall deficit, it is traversed by infrequent cyclones which may provide significant groundwater recharge on a periodicity of a few decades (Allen, 1991).

Groundwater recharge is actually enhanced where the vegetation is sparse, and where runoff can concentrate in closed sandy depressions. In the northern Eucla Basin, depressions known as dongas, several kilometres across, are effective in concentrating and recharging infrequent runoff (Commander, 1991). Geological structure is also important, allowing recharge around the edge of the Simpson Desert, where the Jurassic sandstone crops out.

Estimates of groundwater recharge in desert areas have generally been about 1% of annual rainfall (Jacobson and Lau, 1983), representing only about 2 mm/year. Groundwater discharge to the sea from the Canning Basin suggests a recharge of about 2%, or 6 mm/year (Allen et al., 1992). This contrasts with groundwater discharge from the more densely vegetated, clayey soil, fractured rock environment in the Kalgoorlie Region, which is estimated to be only 0.003% of annual rainfall (Commander et al., 1992).

4. Groundwater age

Groundwater systems in the sedimentary basins in the centre of Australia contain very old groundwater, because of the low groundwater recharge rate, the scale of the groundwater basins and consequent long travel times. Groundwater presently underlying the Simpson Desert, part of a very extensive groundwater system in the Great Artesian Basin, is inferred to have originated in eastern Queensland up to a million years ago, and is therefore likely to predate the formation of the desert itself. Dating has not been carried out on groundwater in the Canning and Officer Basins, but it can also be inferred that this groundwater is of the order of hundreds of thousands of years old. This 'fossil water' leads to the question of sustainability, since the storage is generally many orders of magnitude greater than the recharge rate.

Groundwater basins in North Africa and Arabia, at similar latitudes in the northern hemisphere, contain groundwater originating from a distinct pluvial period some 20 000 years ago. However research in Australia has failed to identify a distinct period of groundwater recharge in the past. The effect of periodic cyclones suggests that recharge has been a continuing process.

5. Sustainability

The possible annual yield of fresh groundwater in most of Australian Deserts has been estimated to be less than 1000 m^3/km^2 (Jacobson and Lau, 1983), however this is a significant quantity over a large area. Allen et al. (1992) identified sources in the Canning and Officer Basins containing 80 GL/a in the Officer Basin below the Great Sandy and Gibson Deserts, and 500 GL/a in the Canning Basin below the Great Sandy Desert.

Because of the very small recharge rate of groundwater, sustainable groundwater use must capture or utilise the rainfall recharge over a large area. If groundwater is to be used for irrigation, a ratio of 100 times the crop area may be needed for groundwater recharge area. Thus sustainable use might be possible only on one hundredth of the desert area. While clearance of vegetation elsewhere in Australia has led to a large increase in recharge, modification of desert environments will have limited effect due to the infrequency of recharge events.

It may be considered that part of the very large groundwater storages in the sedimentary basins could be utilised at a low rate over periods of hundreds of years, given that the groundwater is very old.

6. Groundwater use

Groundwater supplies are very important for Aboriginal communities which have outgrown their traditional surface sources such as rockholes and springs which are rare in desert environments. There are few large communities in the desert. Punmu (population 200), on the fringe of the Great Sandy Desert, is located at fresh water springs discharging to a salt lake, and groundwater from the regional aquifer is at shallow depth and easily exploitable. It is one of the few communities where irrigation is feasible. By contrast at Tjuntjuntjarra on the southern fringe of the Great Victoria Desert there is a very thin layer of fresh groundwater, and the community must resort to desalination.

Pastoral supplies have been successfully established on the coastal fringe of the Great Sandy Desert. Irrigation of cotton and horticultural crops on a commercial scale is also currently under consideration in coastal part of the Great Sandy Desert. Availability of groundwater has not been a factor in limiting development for pilot crops, however the issue of sustainability will have to be addressed for commercial development.

7. Techniques

New techniques for groundwater exploration such as remote sensing and aerial geophysics, can be of some assistance in the desert regions for identifying geological structures and shallow groundwater, but there is already basic knowledge of the hydrogeology of the sedimentary basins.

Experience in artificial recharge, for instance at the Ophthalmia Dam, is useful for alluvial aquifers in the arid zone, but not applicable to large sedimentary basins because of the lack of reliable runoff, and the extensive aquifer systems in which recharge would be dissipated.

The development of desalination for gold mining has drawn attention to the potential of brackish and saline groundwater. Desalination is also an option for a few Aboriginal communities where the local groundwater salinity is high.

8. Conclusion

Australian deserts are underlain by large groundwater resources, however because recharge rates are low, the sustainable yield will allow irrigation of only a fraction of one percent of the recharge area. Groundwater availability, however is seldom a limiting factor for community water supplies, and desert areas often have greater potential for fresh groundwater supplies than adjacent areas underlain by fractured rocks.

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Desert-Inland-Marine Solartopia

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Abstract - The concept of "Desert Aquanet System" is applied to develop Desert-Inland-Marine Solartopia for large scale afforestation in arid region of India. Roof type multiwick solar stills and wind mills are hybridized with PV cell panels to generate 1000 MW of power, breeding of PV cells and afforestation/irrigation of 1000 Km^2 forest lands in arid areas. The system can be applied for scaleless expansion. Establishment of a long and continuous plan with low pressure stills will reduce operating expenses in the long run.

Keywords : Desert irrigation, solar still, afforestation.

1. Introduction

The desert-Inland-Marine Solartopia System combines three basic concepts of,

(a) multiwick solar still system developed at I.I.T.Delhi, India (Sodha and Tiwari, in Press),
(b) roof type solar still system developed at Nagoya University, Japan (Toyam et al., 1991) and
(c) desert aquanet system proposed by a construction company (Mianami, 1990).

Multiwick solar stills have higher efficiency since it requires less saline water in flowing mode than conventional roof type solar still system. A hybrid system comprising PV cells and multiwick roof type solar still is likely to bring down the construction cost as compared to the roof with PV panels only. A higher water-flow will increase PV cell efficiency by lowering operating temperature at the cost of fresh water production and vise-versa. Therefore, the water flow rate can be controlled as per requirement of the fresh water and electricity demand. Electricity demand can also be met by wind energy or desert aquanet system. Desert aquanet system is composed of several artificial lakes filled by sea water. The pumping facility is estimated to be $1000 t.m^3/min$ and 6×10^3 MW for a 30 km diameter and 30 m depth. Seven lakes will be connected by an open channel at 100 m altitude. The construction cost is estimated to be US$ 18 billion for water proof walls and approximately one third otherwise. The sea water pumping to the artificial marine lake is capable of cooling the surrounding territory and providing humid atmosphere, which is expected to stimulate rain fall. These climate changes can be predicted by computer simulations. A brief calculation shows that seven lakes will improve the climate of a 54000 km^2 area (Mianami, 1990).

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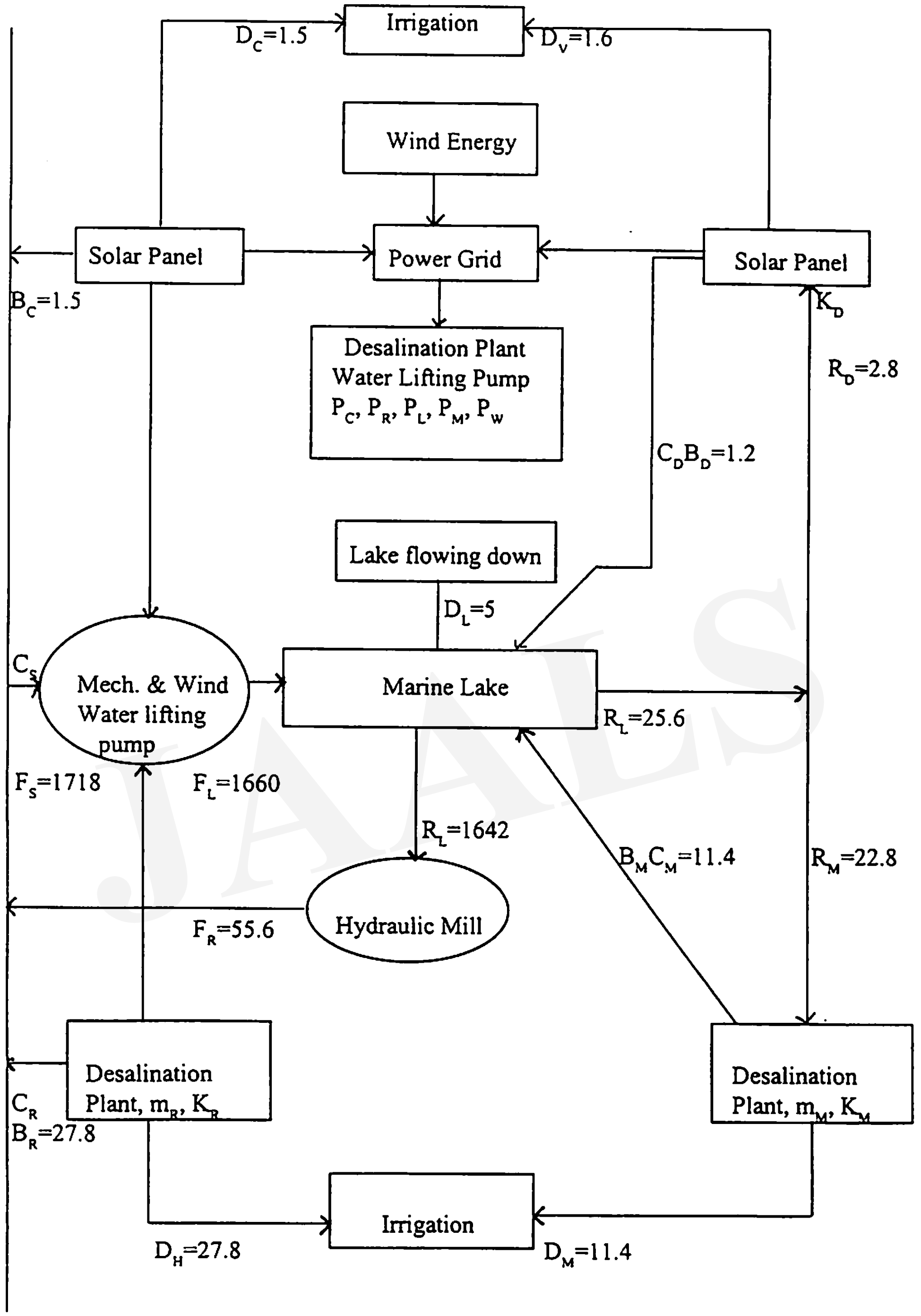

Fig. 1 Mass and energy flow of the system

These concepts are applied for afforestation and climate improvement of arid areas in Rajsthan and Gujarat province of India, including Thar deserts. Desert-Inland-Marine Solartopia (DIMS) is composed of a series of solar stills and photovoltaic system as shown in Fig.1. The roof type multiwick solar stills are hybridized with the PV solar panels and wind mills. High wind speed is utilized both for water lifting and power generation. Power generation by the PV cell panels and wind mills is consumed for PV cell production, and conventional desalination plants. It also augments water lifting capability. Three lakes are constructed 25 km in diameter and 25 meter in depth, connected by open channels. The system is evaluated assuming an energy gain of the PV system of 10, and a life time of 20 years. If the effective area of the PV cell is approximately of 5 km^2, the electricity output will be 500 MW approximately. A part of the sea water is recirculated to the sea to control the concentration at an allowable limit.

2. Mass and Energy Balance

Nomenclature

A_L	:	Surface area of the lake	B	:	Brine flow rate
C	:	Concentration	D	:	Fresh water flow rate
F	:	Sea water flow rate	K	:	Conversion Coefficient
m	:	Concentration ratio	P	:	Power
R	:	Lake water flow rate	V_L	:	Volume of the lake

Subscripts

C	:	Seaside solar still	D	:	Lakeside solar still
I	:	Lake pumping up	L	:	Lake flowing down
S	:	Sea	W	:	Wind
M	:	Lakeside desalination Plant			
R	:	Seaside desalination plant			

The mass and energy balance of the system can be given by the following equations,

Sea water flow

$$F_L = F_W + F_P = F_C + F_L + F_R$$

Seaside still

$$F_C = B_C + D_C$$

Marine lake

$$F_L + B_D + B_M = R_I + R_L + D_L$$

Lakeside still

$$R_I = R_M + R_D \quad \& \quad R_D = B_D + D_D$$

Lakeside desalination plant

$$R_M = B_M + D_M$$

Where, $C_S F_S + C_D B_D + C_M B_M = C_L (R_I + R_L)$

$C_L R_D = C_D B_D$, $R_D = m_D B_D$,

$C_L R_M = C_M B_M$, $R_M = m_M B_M$,

Seaside power

$$P_W + P_D = P_I + P_M$$

Where, $P_C = K_C D_C$, $P_S = K_S F_L$, $P_R = K_R D_R$

$P_L = K_L R_L$, $P_I = K_I R_I$, $P_D = K_D D_D$

K_R = 12 KW.h/m^3 , K_M = 17 KW.h/m^3,

D_C = 1.4 - 1.6 M^3/s, D_D = 1.6,

P_S = 100 MW, P_R = 800 - 1000 MW,

P_M = 400 - 800 MW, m = 2.0

3. Results and Discussions

Results are simulated by varying different parameters in the allowable range and averaging Solar Intensity on an hourly basis. If all produced fresh water is used for irrigation, afforestation areas could be estimated by assuming critical rainfall for cultivation to be 350 mm/year. An arid area over 1000 km^2 can be afforested by this system. New polymers such as Sangarin can be used to retain moisture in the soil and improve microclimate with greater efficiency. However, since PV cells are the main constituent material, its breeding twice in 20 years is likely to reduce irrigation area by approximately 12%. DIMS system would be able to afforest 200 km^2 initially if standards put forth by Murai and Yoshizaki, 1990 are met. This will approximately double after 8-10 years. A cost analysis of the system shows approximately 4 million USD will be required per square kilometer of plantation. This cost may be decreased if artificial marine lakes could be replaced by compact solar low pressure multiwick desalination plants. Low pressure multiwick solar desalination systems for deserts (Sanjay Kumar, 1995) have been studied and proposed by one of the authors earlier. A cost analysis shows that the overall cost would reduce by approximately a hundred times for plantation and subsequent irrigation. The system can be applied at an arbitrary scale on the coast while afforestation will proceed from coastal to inland areas.

References

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