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Desertification Control Bulletin

A Bulletin of World Events in the Control of Desertification, Restoration of Degraded Lands and Reforestation

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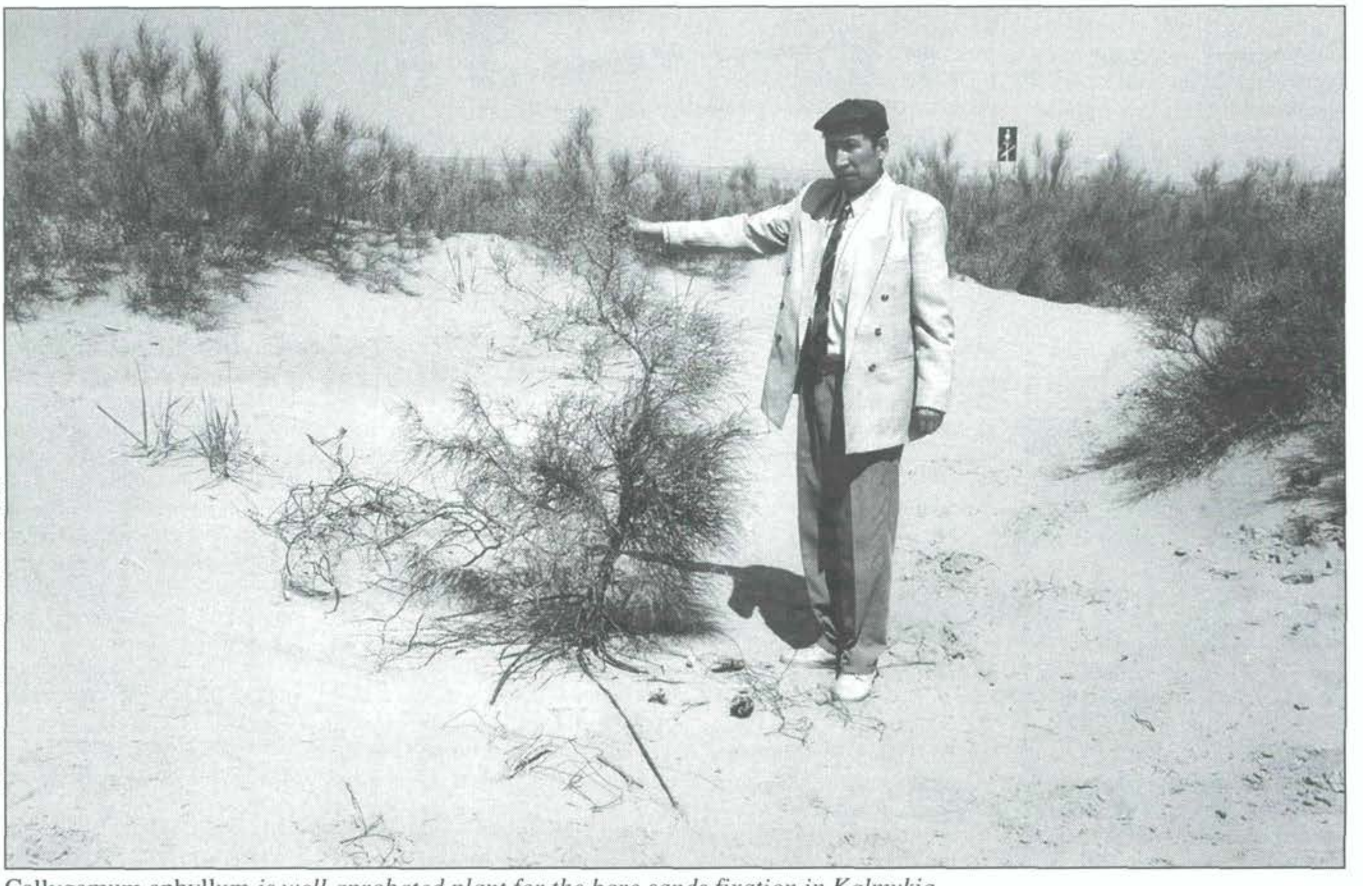

Photo: Leonid Kroumkatchev, UNEP

Callygamum aphyllum *is well aprobated plant for the bare sands fixation in Kalmykia.*

Cover: The burning of Haloxylon recurvum *to produce a hyproduct for cloth washing enhances desertification processes in the Cholistan desert, Pakistan.*
Photo: Mohammad Arshad.

The United Nations Convention to Combat Desertification (CCD) which came into force on 26 December 1996, lays out new measures to be undertaken by governments of affected countries and by those in a position to help. It is a comprehensive treaty, with an innovative participatory approach aimed at involving all stakeholders.

The core of the Convention is the development of national, sub-regional and regional action programmes to combat desertification. National action programmes are to be developed by governments in close cooperation with donors, local populations and non-governmental organizations (NGOs). In contrast to many past efforts, these action programmes must be fully integrated with other national policies for sustainable development. They should be flexible, able to be modified as circumstances change.

For this approach to work it is essential that people at all levels are aware of the strengths of the drylands, as well as the causes and mechanisms of desertification and of possible solutions to the problems. Accordingly the UN-CCD emphasizes the increasing need to raise awareness and knowledge of dryland issues globally, particularly among government decision makers, affected and non-affected community groups, donors, international partners and the general public.

More than 6.1 billion ha, 47.2% of the Earth's land surface, is dryland. Nearly 1 billion ha of this area are naturally hyperarid deserts, with very low biological productivity. The remaining 5.1 billion ha are made up of arid, semiarid and dry subhumid area, part of which have been degraded since the dawn of civilisation while other parts of these areas are still being degraded today. These lands are the habitat and source of livelihood for about a fifth of the world's population. They are areas experiencing pressures on the environment caused by human mismanagement, problems that are accentuated by the persistent menace of recurrent drought.

One of the main aims of the bi-annual Desertification Control Bulletin is to disseminate information on, knowledge of, desertification problems and to present news about the programmes, activities and achievements in the implement-ation of the CCD around the world. Articles published in the *Desertification Control Bulletin* do not imply the expression of any opinion on the part of UNEP concerning the legal status of any country, territory, city or area, or its authorities, or concerning the delimitation of its frontiers or boundaries.

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Cover Photographs

The Editor of *Desertification Control Bulletin* is seeking photographs for consideration as bulletin covers. All submissions should be addressed to the editor at the above address.

Technical requirements

Photographs must be colour transparencies of subjects related directly to desertification, land, animals, human beings, structures affected by desertification, control of desertification, reclamation of desertified lands, etc. Submissions must be of high quality to be enlarged to accommodate a square 18 cm x 18 cm (8 in x 8 in).

Captions

A brief caption must accompany each photograph giving a description of the subject, place and country, date of photograph and name and address of photographer.

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Articles

Desertification Control Bulletin invites articles from the world's scientists and specialists interested in the problems arising from or associated with the spread of desertification.

Audience

The bulletin addresses a large audience which includes decision makers, planners, administrators, specialists and technicians of countries facing desertification problems, as well as all others interested in arresting the spread of desertification.

Language

The bulletin is published in English and Spanish. All manuscripts for publication must be in English.

Manuscript preparation

Manuscripts should be clearly typewritten with double spacing and wide margins, on one side of the page only. The title of the manuscript, with the author's name and address, should be given in the upper half of the first page and the number of words in the main text should appear in the upper right corner. Subsequent pages should have only the author's name in the upper right hand corner. Users of word-processors are welcome to submit their articles on diskette in MS-DOS format, indicating the programme used.

Metric system

All measurements should be in the metric system.

Tables

Each table should be typed on a separate page, should have a title and should be numbered to correspond to its point in the text. Only essential tables should be included and all should be identified as to source.

Illustrations and photographs

Line drawings of any kind should each be on a separate page drawn in black china ink and double or larger than the size to appear in the bulletin. They should never be pasted in the text. They should be as clear and as simple as possible.

Photographs in the bulletin are printed black and white. For satisfactory results, high quality black and white prints 18 cm x 24 cm (8 in x 10 in) on glossy paper are essential. Diapositive slides of high quality may be accepted; however, their quality when printed black and white in the bulletin cannot be guaranteed.

All line drawings and photographs should be numbered in one sequence to correspond to their point of reference in the text, and their descriptions should be listed on a separate page.

Footnotes and references

Footnotes and references should be listed on separate pages at the end of the manuscript. Footnotes should be kept to an absolute minimum. References should be strictly relevant to the article and should also be kept to a minimum. The style of references should follow the format common for scientific and technical publications; the last name(s) of the author(s) (each), followed by his/her initials, year of publication, title, publisher (or journal), serial number and number of pages.

Other requirements

Desertification Control Bulletin publishes original articles which have not appeared in other publications. However, reprints providing the possibility of exchange of views and developments of basic importance in desertification control among the developing regions of the world, or translations from languages of limited audiences, are not ruled out. Short reviews introducing recently published books in the subjects relevant to desertification and of interest to the readers of the bulletin are also accepted. Medium-length articles of about 3,000 words are preferred.

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International Events on Desertification Control

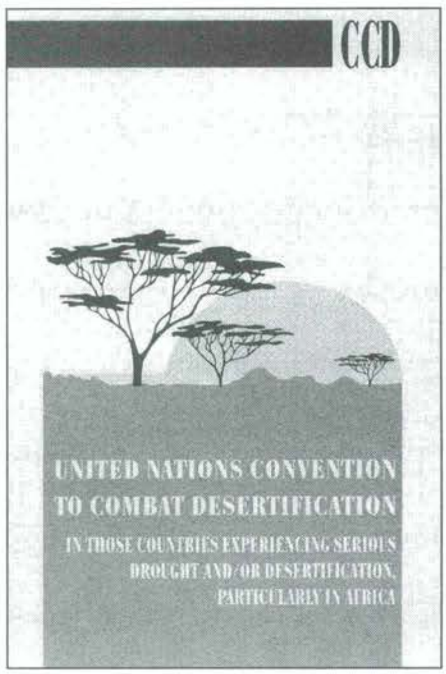
The Third Conference of the Parties to the Convention to Combat Desertification

15 to 26 November 1999, Recife, Brazil.

The Conference of the Parties (COP) will oversee the implementation of the Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa. It is established by the Convention as the supreme decision-making body, and it will comprise all ratifying governments (regional economic integration organizations, such as the European Union). Once the Convention enters into force, the COP will meet at least once a year for its first four sessions. One of its main functions will be to review reports submitted by the Parties detailing how they are carrying out their commitments. The COP will make recommendations on the basis of these reports. It also has the power to make amendments to the Convention or to launch negotiations for new annexes, such as additional regional implementation annexes. In this way, the COP can guide the Convention as global circumstances and national needs change. To assist the COP, the Convention provides for several supporting bodies and allows the COP to establish additional ones if necessary.

The first Conference of the Parties (COP-1) to the United Nations Convention to Combat Desertification (CCD) met in Rome, Italy, from 29 September to 10 October 1997. The second Conference of the Parties (COP-2) met in Dakar, Senegal, between 30 November and 11 December 1998.

The third session of the Conference of the Parties (COP-3) is scheduled to take place in Recife, Brazil from 15 to 26 November 1999. A brief summary of COP-3 will be given in the Desertification Control Bulletin, issue No. 36.



The Role of Business in Sustainable Development

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Introduction

Industrial, agricultural and other business activities place too much stress on the natural environment. Industrial and agricultural emissions of carbon dioxide, methane and other greenhouse gases contribute to a warmer planet. Reducing the output of these climate-changing gases will require a fundamental shift in how we manufacture products, grow food and use energy. The issue of climate change and economic development are thus closely interrelated. Sustainable development derives its fundamental value from the recognition that the world's ecology and its economies are interlocked. It is argued that it is not only good business practice to undertake sustainable development initiatives, but that if we are to resolve environmental problems, the business community must play a vital role. Management needs to integrate the concept of sustainable development into the planning and measurement systems of individual business enterprise.

At present several areas of sustainable development are technically ambiguous and the role of business in contributing to sustainable development is still a moot point. It is generally agreed that sustainable development is a social goal and that all elements of society must share in and work co-operatively to achieve the goal. It is common for those in authority to be sufficiently removed from the land that they do not consider, as a priority, any endeavour to counter environmental problems. Even the most enlightened government or agency equivocates and tries to weigh the readily apparent short-term labour/economic costs and/or forgone benefits against possible future long-term benefits from environmental control efforts. Some executives consider the principal objective of business is to make money; others see a broader social role. There is little agreement among business leaders as to the balance between moral self-interest (within the law) and self-imposed restraint for the social good. Sustainable development and environmental responsibility are currently in the centre of this corporate and social policy conflict and decision-making (IISD, 1992).

It is the aim in this brief article to present a business perspective to the concept. In particular, an attempt is made to explain sustainable development from a practical business standpoint and to identify the challenges confronting business management as it tries to integrate environmental and sustainable issues into its operations.

Definition

The term 'sustainable development' first came into prominence in 1980, when the International Union for Conservation of Nature and Natural Resources (IUCN) presented the World Conservation Strategy (WCS) with the overall aim of 'achieving sustainable development through the conservation of living resources'. The World Commission on Environment and Development (WCED) in 1987 became the first organization to popularise the concept by identifying sustainable development as the basic goal of society, while reconciling the interests of the development community with those of the environmental movement. In *Our Common Future*, the WCED blueprint, sustainable development is defined as 'development that meets the needs of the present without compromising the ability of the future generations to meet their own needs'. A key feature of the concept is its potential to integrate environmental and economic factors into decision making, along with the implications of those factors for the well-being of people. For example, the concept integrates concern for environmental protection with concern for poverty reduction, so that people are not forced to destroy their environment to achieve their economic objectives. It integrates market choice and competition with the need to ensure that such economic activity does not destroy the physical and ecological systems that support it. In brief, the concept integrates macro-level economic theory with the business and competitive realities that face individual enterprises (IISD, 1992).

Implications

The fact that forests everywhere in the tropics are disappearing, the ozone layer is being depleted and that global warming is occurring are a few indications that the world today is sacrificing the legitimate needs of future generations. UNEP's recent assessment of land degradation and desertification reveals that about 1.6 billion hectares, or 70 per cent, of the world's agriculturally used drylands have been degraded. These lands have lost 25 per cent or more of their fertility and the process is still going on. During the last thirty years the world lost nearly 200 million hectares of tree cover, an area roughly half the size of the USA. Thousands of plant and animal species, which were found on our planet thirty years ago no longer exist.

A daunting task faces the world community as a result of the global environmental crisis, and the world's business community cannot afford to stand aloof. One earth, ever smaller even as it grows more stressed, it is now a cliché that poverty is the root cause of our global environmental woes. Less well admitted or publicised is the fact that the main businesses that control our global economy are the prime culprits.

For example, the build up of greenhouse gases – carbon dioxide, CFCs, methane, nitrogen oxide, ozone – that prevents the escape of heat from the earth's surface and making our planet overheat is the result of fossil fuel burning, agricultural practices and deforestation. The main engines that drive our global economy are the main causes of greenhouse gases. The greater part of the solid waste and liquid waste that pose health hazards in cities and the effluents that give rise to eutrophication in lakes, rivers and seas are largely the result of business activities, from farms to factories, that threaten our very existence as humans. Unfortunately, the north's pattern and character of industrialization, which most of the developing world is emulating, is on a collision course with the natural environment. The pollution of groundwater and food by industrial and agro-chemicals; acid rain; the appalling prospects of accumulating what are, for all practical purposes, permanently lethal radioactive wastes; the destruction of forests and the erosion of arable lands – all these have become the danger signals that have become visible in the past three or four decades.

And what are these signalling? They seem to be pointing to the fact that, even in and around our developing world, people are on the way to becoming an endangered species.

Many developing countries depend to a large extent on primary production to service their debts as they try to provide basic incomes for their citizens. However, the very act of producing primary products for export usually has dire consequences for the environment. For example, increased mining to provide precious metals and industrial raw materials has disrupted more and more of the land surface and has threatened plant and animal species. Botswana's heavy dependence on beef exports in the past had wrought land degradation from overgrazing. In Papua New Guinea (PNG), where this author had worked and studied the environmental situation, logging activities are contributing to the gradual diminution of the country's forest resources and accelerating the incidence of land degradation (Darkoh, 1996). Revenues or royalties from clear-cutting operations in PNG have hardly ever reflected the cost or amount of damage done to the environment and society by such logging activities, or the cost of rehabilitating the denuded landscapes which are the result (Darkoh. ibid.). In several cases throughout the developing world, the result of such increased primary activities has been the acceleration of desertification, which can be described as the slow and insidious process of ecological degradation of dryland resource systems (Darkoh, 1998).

Currently, under the so-called Structural Adjustment Programmes, several developing countries are forced to increase primary production, lower tariffs on imports, cut back on public sector entrepreneurial activities and privatise state-owned industries. In response, more countries in the developing world are introducing legislation to attract foreign capital and foreign businesses. There is an undue emphasis on production for export, sometimes to the neglect of basic and domestic community needs of food, shelter and clothing. There is a real risk that short-term gains in production for export or growth of gross national product create an illusion of progress, while land degradation develops largely unheeded until the problem becomes severe (Barrow, 1991). As globalization intensifies and more countries open up their borders and economies to foreign capital and business, and as urbanization and industrialization gain momentum in these countries, the developing world faces the worst effects of economic development – widespread pollution and land degradation.

In sub-Saharan Africa, the sub-continent's natural resource base is being dismembered. The productivity of the savannas, where most of Africa's population lives, has dropped by 35 per cent. Over 50 million people live on land so badly degraded that they are frequently at risk from famine. Over and above resource destruction, a recent report discovered, for the first time, high levels of ozone and acid rain pollution associated with industrialization over virgin forest of Central Africa (Tolba, 1989). Today, air pollution in some parts of Africa is fast approaching levels in Europe, South-East Asia and North America. Thus Africa faces the worst effects of industrialization – widespread pollution – without reaping the benefits of industrialization: economic growth. Furthermore, in recent years, Africa has been facing the disconcerting threats of toxic terrorism. The UNEP Governing Council, at its seventeenth session in Nairobi in May 1993, reported that large amounts of hazardous waste have been exported, or are proposed to be exported, to developing countries, particularly in Africa, from industrialized countries.

The examples above have been cited to show that it is not only the poor who are responsible for the environmental disaster facing the world today, but that the greater part of the blame should go to the big businesses that control our global economy. Of course, not all businesses are culprits. Nor should the poor be exonerated. In fact, it is not our aim in this article to apportion blame as such, but to point out that in its own interest, as well as the interest of society as a whole, business activity must become more environmentally responsible.

It is clearly in the interest of business to operate within a healthy environment and economy. Protecting an enterprise's capital base to ensure its financial sustainability is a well-recognised business principle and business should accept the idea of extending this notion to the world's natural and human resources (IISD, 1992). This is one of the challenges posed to the business world in a global economy that is currently under pressure.

There are forms of development that are environmentally and socially sustainable; development that leads not to a trade-off, but to an improved environment, development that does not draw down our environmental capital, but rather maintains it. Such activity involves not only agricultural land but also the absorptive capacity of the atmosphere, soil and water.

Business decisions are crucial to environmental protection. They guide the design and marketing of environmentally benign or harmful products, the development and diffusion of clean or dirty technologies and the conservative, or profligate, use of natural resources. If we are to resolve environmental problems nationally and internationally, the business community must play a vital role. For the business enterprise, sustainable development should mean the adoption of business strategies, ethics and activities that not only meet the needs of the enterprise and its stakeholders today but also and, perhaps more importantly, sustain and enhance the human and natural resources that will be needed in the future.

The above definition which focuses attention on areas of specific interest and concern to business has recently been proposed by the International Institute for Sustainable Development (IISD) to help business executives and directors apply the concept of sustainable development to their own organizations. The definition captures the spirit of the concept as proposed in the report of the World Commission on Environment and Development (WCED, 1987). It recognises that economic development must meet the needs of the business enterprise and its stakeholders. The latter includes shareholders, lenders, customers, employees and suppliers and communities who are affected (either positively or negatively) by the enterprise's business activities. Clearly, a broad range of people and entities have a stake in business enterprises even if they do not share in the profits. Business enterprises have a moral, if not legal, accountability to these diverse groups.

The definition also throws light on the dependence of the enterprise's economic activities on human and natural resources, in addition to physical and financial capital. It stresses that economic activity should not irreparably degrade or destroy these natural and human resources. Human resources refer to all people affected directly by the economic activities of the enterprise including employees and the public generally.

However, as the IISD has emphasized, sustainable development cannot be achieved by a single enterprise (or, for that matter, by the entire business community) in isolation from the rest of society. Sustainable development is a pervasive and persuasive philosophy to which every participant in the global economy (including consumers and government) must subscribe if we hope to meet today's needs without compromising the ability of future generations to meet their own. Only an avid and irresponsible company that is interested only in making money would dismiss the idea of integrating environmental considerations into every aspect of business life. Such narrow self-interest should not be tolerated.

Technology

While technologies are crucial for the way we live and our standard of living, they are also central to the way we interact with the natural environment. On the grounds, at least, of resource and environmental conservation, the search should be on for technologies, ways of producing necessary goods and services, that are more sparing in their use of non-renewable resources and, as far as humanly possible, non-violent towards the living environment (Ross and Usher, 1986).

The technology needed to clean up past problems and minimise or eliminate environmentally negative processes or products is advancing rapidly. Other new technologies with implications for the environment currently being developed include:

- waste-related technology, comprising recycling and re-use;
- new energy sources, such as solar cells for houses;
- new automobile technology, for example developments in lean-burn engines, methanol-driven cars, etc.;
- CO_2-related technologies, for example removing CO_2 from industrial emissions, re-use of CO_2 for synthesis of chemicals such as methanol; marine temperature power generation;
- Technologies for use in the fight against desertification in the world's productive drylands, for example techniques for stabilising soil and conserving runoff water.

Many of the technologies listed above represent advances in component design allowing the greatest improvement in the long term. Developing countries should make informed choices as to which technology is most appropriate in their particular circumstances. The developed world does not have the monopoly of all technological wisdom, nor are excellent technical solutions to environmental problems in the advanced countries necessarily appropriate for similar problems in poorer countries (Darkoh, 1999). The circumstances are not the same, and indigenous knowledge and intermediate technology in developing countries should also provide a wide arena for business to explore and adapt for environmental sustainability. However, government and economic policies should endeavour to encourage the adoption of relevant advances or cease to favour the continued use of older, inefficient and dirty technologies. The adoption of new industrial technologies, ITK and intermediate technologies have, in particular, environmental ramifications. In addition, information, organization and policy are often as important as the availability of new technologies.

Agenda 21 of the United Nations Conference on Environment and Development notes that new and efficient technologies will be essential to increase capabilities (in particular those of developing countries) to achieve sustainable development, within the world's economy, protect the environment and alleviate poverty and human suffering. Inherent in such pursuits is the need to address the improvement of technology currently used and replace it, when appropriate, with more accessible and more environmentally sound technology.

There should be proper technology assessment and in-depth consideration of environmental impacts if the adverse effects of new technologies are to be reduced or avoided altogether. It should be better understood that the extra cost caused by the Environmental Impact Assessment (EIA) of a project, and by any modification which the EIA may suggest in the planning, design and execution of the proposed project, will generally be far below the cost of rehabilitation, reclamation or other corrective measures. Environmental information also needs to be available before technologies reach the market and adverse effects in the environment materializes, since once important investments have been committed to a technology, it becomes very difficult and costly to change course.

Legislation and its enforcement are prerequisites of environmental control and sustainability. For effective environmental legislation, environmental standards and quality controls policy have to be established, coupled with scientific monitoring of pollutants in air, water and soil as well as the level of liquid and solid wastes. In order to enforce pollution laws, government, through its established agencies, must set up national standards laboratories for the monitoring of pollutants in food, drugs and feed. This also involves the training of competent technicians to perform the complicated, though routine, analysis of river water, the air around the factories, agricultural soils, processed food and feeds and drugs. The standards laboratories would carry out routine monitoring tests and alert relevant government agencies to the appropriate law enforcement measures to be taken against defaulters. In no circumstances should any country allow industrial or business concerns (even government-owned) to monitor their own defaulting. Nor should governments, however poor, allow an industrialized country to dump its toxic wastes on any part of its domain on the guise of setting up an industry to recycle wastes. This can happen to any government in a developing country in its eagerness to industrialize, earn foreign exchange and provide jobs. Environmental laws and policies can reinforce efficiency in resource use and provide incentives for adopting less damaging technologies. Under no circumstances should environmental legislation and enforcement be allowed to take a back seat to the push for development.

Challenges for management

The protection of renewable resources, our air, water and land, as well as the wise and efficient use of non-renewable resources are of the utmost importance if our global economic system is to continue to develop and prosper, and if economic progress is to avoid sacrificing the legitimate needs of future generations. This fact must be central to the decisions of individuals, corporations, and governments, if we are to meet the needs of both present and future generations.

For the business world, sustainable development requires that management considers the effects of its activities on the environment and on the long-term interests and needs of stakeholders. Management should decide what strategy to adopt and how to incorporate stakeholders' expectations into a broad policy statement that sets forth the organisation's mission with respect to sustainable development (IISD, 1992).

Other crucial challenges to management are:

- how to tackle or arrange the growing accountability for continuous improvement towards sound environmental management;
- how to reshuffle corporate reporting policies and procedures and what to do in relation to public policy, standard setting and action plans.

All these issues boil down to the crucial question of what is acceptable and what actions management and business enterprises must take to ensure social, economic and environmental sustainability so that present and future generations can meet their needs.

Change is all around us; the world is changing as never before. The successful business will recognise that it must rise to the challenge to change and take advantage of opportunities that come with it.

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Concept of Desertification in the Southern Russian Federation

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Introduction

Many Russian researchers have devoted considerable energy to the study of desert regions in mid and Central Asia, the Near East and North Africa. Between the 1930s and 1940s the eminent Russian scientists, Prof.A.Gael and Prof.M.P.Petrov, developed a new line of research – desert environment studies. The explorations in Middle Asia made the Turkestan deserts the most extensively studied areas in the Eurasian desert domain. Under new conditions in the Russian Federation desertification studies required a new approach, through the examination of composition, structure, function and dynamics of the transition phase between arid, semi-arid and dry humid zones along the northern margin of the Eurasian desert area.

The concept of zonal ecotone in the exploration of desertification in southern Russia

Transitional para-arid latitudinal zones extend along the present-day frontier of Russia from the Caucasus in the west to Dauria in the east. The para-arid zone goes from true desert in the south through sub-zones of semi-desert, steppe desert, dry steppe and true steppe to forested steppe, meadow steppe and dry woodland in the north. These are typical para-arid zonal ecotones described by specific meridianal ecological succession.

[**NOTE:** The term 'para-arid' from *para*, Greek for 'around', and *arid*, Latin for 'drought-afflicted', denotes the transitional zone around true arid and dry humid sub-zones. The term 'zonal ecotone' represents the transition between adjacent zonal biomes where different vegetation types change from one to another in concurrent conditions (Walter, 1976). For example, the zonal ecotone biome is a case of sub-desert including mixing of sagebrush desert patches and short grass steppe patches.]

It is well known that the ecotones are extremely sensitive to ecological changes; their ecosystems are least tolerant to anthropeic disturbances and they serve as an indicator of ecological deterioration. Thus, the desertification of para-arid ecosystems in transitional zones is considerably more than in the true deserts of the central Eurasian domain. This edge effect of para-arid transitional zones was formerly observed not only along the borders of Eurasia, but also along northern African divisions (for example, it is now universally known that powerful indicators of desertification are dust storms of great intensity and of frequent occurrence, along the periphery of desert lands.) So, the strong desertification indicators are extensively distributed in the marginal para-arid zones.

It is recognised that desertification in marginal zones of arid areas is more ecologically dangerous than in central zones. It is explained by the fact that the true desert ecosystems are better adapted to extra-arid conditions than the para-arid ecosystems in the fringe desert regions. So, bare unfixed sands in the northern dry humid arid zone on psammophilous steppe, dry forest steppe, light coniferous tree stands and shrub thickets on sand landscapes (for example, the Archadinskye sands in the Rostov district, the Semiozernye sands in the Kustanay district, the Chaloy sands in the Ulan-Ude district) have no true psammophilous species for sand fixation.

Finally, the northern marginal para-arid zones of the Eurasian desert region exert significant economical effects on ecological and agricultural human existence. Desertification affects the para-arid heavily populated districts inhabited by tens of millions of people. Degradation of dry lands causes damage to pastures, crops, plantations, phytomeliorations, irrigations, water constructions, settlements and industries. Thus, the Russian basic concept of desertification studies consists of the study of composition, structure, function, and dynamics of zonal para-arid ecotone of the northern limit of the Eurasian desert domain.

Concept of bioclimatical zonality of desertification in southern Russia

Zones of desertification are defined by the location of xeromorphous vegetation and soil types and by distribution of bioclimatic aridity indices. First, the zonal

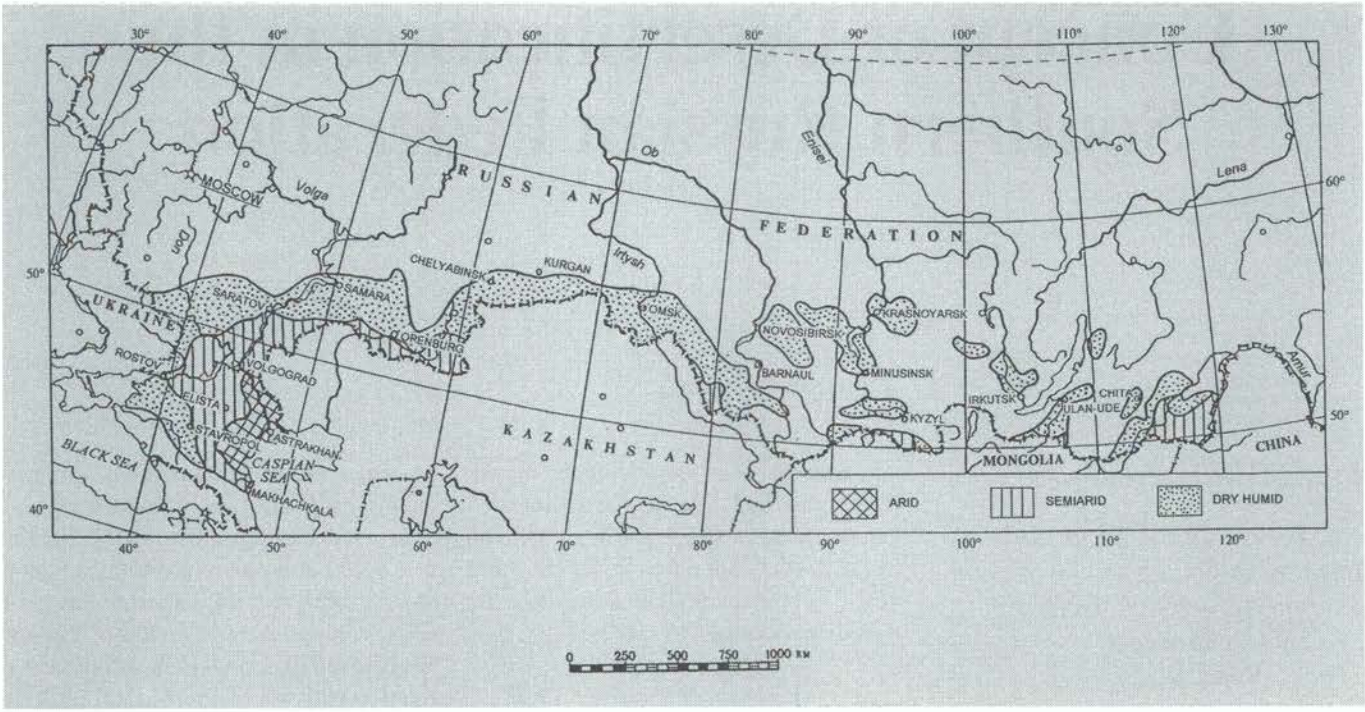

Figure 1. *Map of arid bioclimatic zones in Southern Russia, compiled by vegetation types map (Sochava, 1964) and by aridity index M.I.Budyko P/PET (Budyko, 1974), M.1:25 000 000, where: 1- arid with P/PET 0.05-0.20; 2 - semiarid with P/PET 0.20-0.50; 3 - dry humid with P/PET 0.50-0.65 (Vinogradov, 1997a).*

map of current desertification was generated by the vegetation small-scale map of xeromorphous formations in southern Russia to the scale 1:15 000 000 (Sochava, 1964). Second, these zones of current desertification were revealed by bioclimatic aridity indices, which could be computed by a relationship of an average annual precipitation (*P*) to an annual evatranspiration (*PET*) (Budyko, 1974). This bioclimatic aridity index was taken from the Map of the World Distribution of Arid Regions (UNESCO, 1977). Then, superposition of pictures of the vegetation map (Sochava, 1964) and the bioclimatic aridity index location (UNESCO, 1977) produced the map of zonal arid ecotones of southern Russia, scale 1:25 000 000 (Vinogradov, 1997) (figure 1). On this map of arid ecotones in southern Russia we have attempted to trace three para-arid zones: arid, semi-arid, and dry humid.

The (true) arid zone (according to bioclimate classification by UNESCO, 1977) or the northern desert (or southern sub-desert) ecotone zone (according to landscape classification by Vinogradov, 1997), fringes the Eurasian desert region to the north and covers nearly 70,000 km^2. Mean annual precipitation *P* is between 100 and 200 mm, aridity index *P/PET* is between 0.05 and 0.20. A typical land unit includes euxerophilous saltwort/sagebrush vegetation on brown solonetz desert soils. Dry farming is impossible.

The semi-arid or sub-desert (or deserted steppe) bioclimatic and landscape zone presents the main transitional northern margin of the Eurasian desert domain and covers an area of 320,625 km^2. Mean annual precipitation is 200 to 400 mm, aridity index *P/PET* is 0.20 to 0.50. A typical land unit consists of xerophilous short grass/sagebrush vegetation on light chestnut solonetz soil. Dry farming is restricted to irrigated valleys and wet depressions.

The dry sub-humid or dry steppe zone sets a limit to the northern Eurasian desert domain and covers a larger area of 830,000 km^2. Mean annual precipitation *P* reaches 400 to 600 mm, aridity index *P/PET*, 0.50 to 0.65. A typical land unit is noted for mesoxerophilous herb/short grass vegetation on true chestnut and carbonate chernozems. Dry farming is possible on plains but risky.

In the case of Russian climatic conditions G.T. Selyaninov (1937) pioneered the application of hydrothermic aridity index (HTAI), which is appropriated:

HTAI=$\sum$/St,

where $\sum P$ = the sum of a precipitation (in mm) in a year, $\sum$= the sum of an average daily temperature (over 10^0 C). By this means bioclimatic values were computed from HTAI = 0.5 corresponding to the northern limit of the true desert

Bioclimatic aridity zones	Bioclimatic aridity indexes P/PET	Size of aridity zones in Southern Russia (in km^2)
Arid	0.05-0.20	70 000
Semi-arid	0.20-0.50	320 625
Dry humid	0.50-0.65	830 000

domain and 1.0 to the northern limit of the true steppes.

Unlike the aridity index in the Map of the World (UNESCO, 1977) we use modified bioclimatic aridity index under boreal conditions of Southern Russia adapting to a fresher continental climate (Mezentzev, Karnatzevitch, 1969). This boreal bioclimatic aridity index (AI) is estimated as the difference between the sum of mean monthly temperatures for the warm period from April to October $\Sigma_{IV\text{-}X}\, t$ with empirical coefficients 5.12 and 306 to the sum of a mean monthly precipitation $\Sigma_{I\text{-}XII}P$:

$$AI = \frac{\Sigma_{IV\text{-}X}t - 306}{\Sigma_{I\text{-}XII}P}$$

This formula of bioclimatic aridity index (AI) was successfully employed in the preparation of the small-scale map of aridity lands (Lobova, Ostrovsky, Khabarov, 1977). By applying the Russian version of bioclimatic aridity index we outlined the main zones of aridity in southern Russia.

Regional mapping of the bioclimatic aridity index was compiled at the scale 1:1 300 000 over the Kalmykian Test Area (the Elista district) as a model of desertification levels (Vinogradov et. al., 1995). AI of this Test Area was estimated for 17 meteorological stations over an area of about 50,000 km^2. The machine computation was performed for data gathering for the ecological stable state time interval of 1950 to 1960. Then, isolines of bioclimatic aridity indexes were stretched by 17 counts with the *Kriging* procedure by the *Surfer* program (figure 2). This procedure was effectively employed in regional bioclimatic aridity index mapping.

Over the Kalmykian Test Area (the Elista district) the strong arid area with AI > 0.70 covers the small south-eastern section. The medium arid area with AI = 0.60-0.70 occupies the greatest space of the Central Kalmykia (including the Black Lands sands). Strong arid areas have mean annual precipitation of less than 250 mm, medium arid 250 to 300 mm. These arid zones are occupied by saltworth/sagebrush vegetation on brown silt soils, cover sands, and saline grounds. The bioclimatic aridity levels correlate with landscape zones: the strong arid area corresponds to true deserts, the medium arid area to southern sub-deserts. This area has a high risk of anthropeic disaster desertification.

The moderate arid area with AI = 0.50-0.60 occupies the western part of the Kalmykian Test Area with a mean annual precipitation of 300 to 400 mm. This area

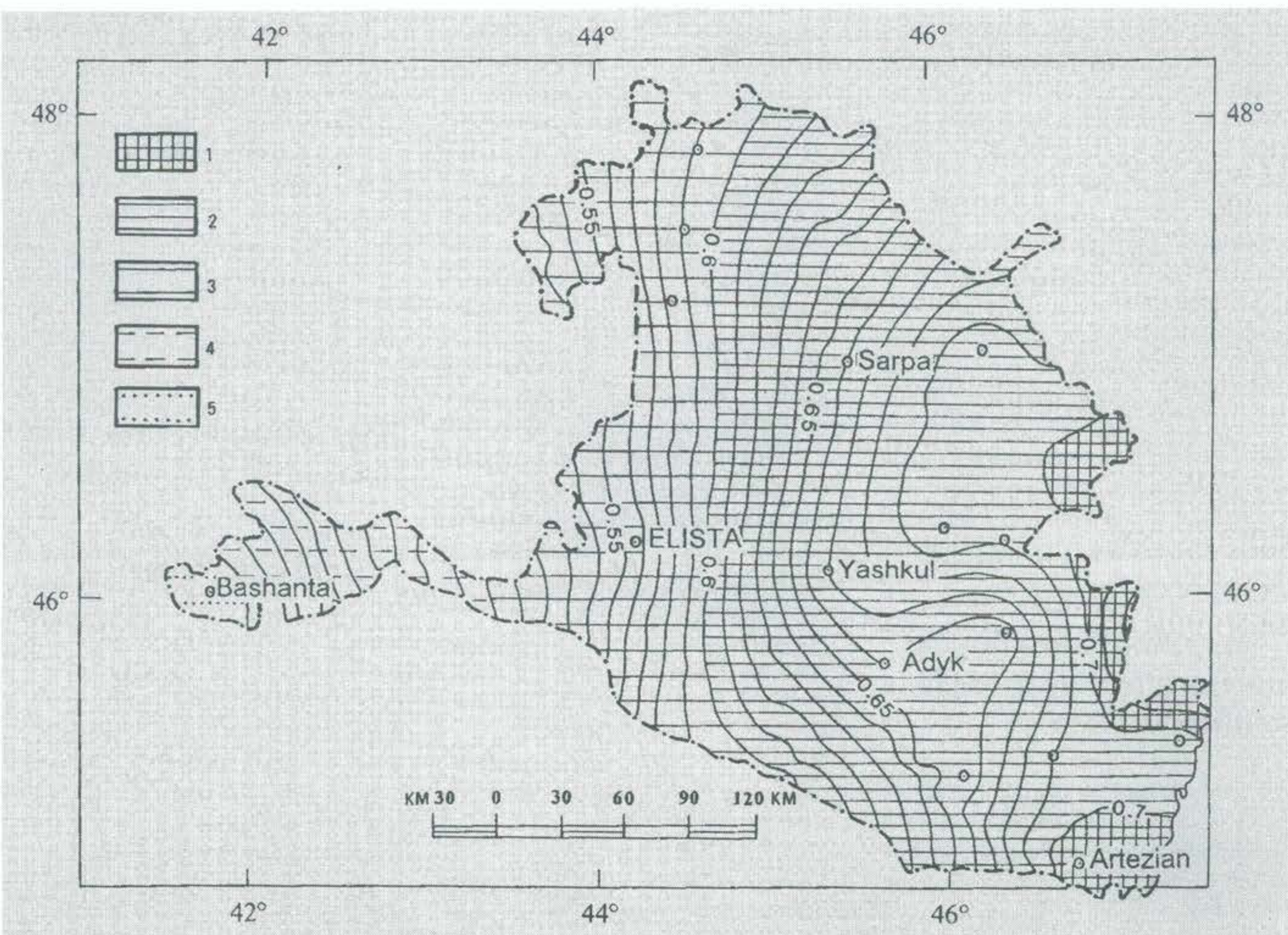

Figure 2. *Map of arid bioclimatic regions in the Kalmykia (Elista district), compiled by aridity index (AI) (Vinogradov, et. al., 1995), where: 1 - strong arid with AI > 0.70; 2 - medium arid with AI 0.60-0.70; 3 - moderate arid with AI 0.50-0.60; 4 - slightly arid with AI 0.40-0.50; and 5 - periodically arid with AI < 0.40.*

is covered by short-grass vegetation on light chestnut silt soils. The moderate arid area corresponds to the northern sub-deserts or stepped deserts. This area may be subjected to a medium risk of anthropeic desertification.

Finally, the slight and periodical arid areas with AI < 0.50 occupy a small part of the western border of the Kalmykian Test Area, where mean annual precipitation exceeds 400 mm. According to the Map of the World (UNESCO, 1977) these areas are referred to as a dry humid zone. The area is typified by dry farming, short-grass vegetation on chestnut soils and southern chernozems. This area has a low risk of anthropeic desertification.

Thus, bioclimatic zonality of desertification phenomena covers true deserts, sub-deserts, dry and true steppes, xerophillous woodlands, barren lands, and other deteriorated areas. In the Russian Federation desertification processes may be manifested by a wide range of signs and symptoms. These desertification occurrences cover the European domain within stated limits of many districts: Elista, Kizlyar, Astrakhan, Stavropol, Volgograd, Rostov, Saratov, and Orenburg; in the Asian domain: Chelyabinsk, Kurgan, Omsk, Novosibirsk, Barnaul, Minusinsk, Kyzyl, Irkutsk, Ulan-Ude, and Chita. The northern border of the desertification phenomena crosses the Lower Don, the Middle Volga, south of West Siberia, west of the Altay, south of Middle Siberia, south of the Dauria. Over them, the Russian boreal para-arid ecotone extends to foreign areas south of Ukraine, north of Kazakhstan, north of Mongolia and north of China, where desertification symptoms are also observed.

Geographical distribution of desertification areas in southern Russia

The northern zonal para-arid ecotones of the Eurasian desert domain are extended in a latitudinal direction from the Dunibe on the west to Manchuria on the east. These marginal para-arid ecotones cover the south of Ukraine, the south of Russia, the north of Kazakhstan, the north of Mongolia, and the north of China. Within the current Russian territory there are four sector provinces: the East European-Near Precaspian, the West Siberian-Altay, the Middle Siberian-Sayan, and the East Siberian-Daurian.

Desertification in the East European-Near Precaspian province

Severe desertification is best shown over the arid zones in the east-southern Near Precaspian province (the Elista, Astrakhan and Kizlyar districts). It should be said that here the greatest desert in Europe is found (Gabunshina, 1998). In these districts we observe much evidence of desertification: heavy overgrazing, pasture deterioration, scarp deflation, sand-blown soil salinization, severe dust storms, etc. Around this desert area dry steppes are distributed in the Rostov, Stavropol, Volgograd, Saratov and Orenburg districts. In these districts many obvious indicators of desertification include sheet and deep soil erosion, humus loss, loess deflation, soil salinization and pollution. Thus, all aridity levels are represented in this province from strong arid to periodical arid (dry humid) areas.

The Elista district is one of the most extensively studied desertification areas in the Russian Federation (Bananova, 1990; Vinogradov, 1993). Desertification in the Elista district is due to severe overgrazing of pastures, rapid drying of wetted meadow and flooded depressions, deep soil salinization of unrepaired and abandoned irrigated systems, formation of solonetz, ploughing of non-arable soils, sand deflation and dust storms. The desertification processes have been monitored for the last 40 years. Land degradation of the Black Lands was measured in terms of a decrease of cattle forage more than once, the area of bare blown sands increased more than tenfold. In the Elista district between 1954 and 1994 we run down slight, moderate, severe and very severe desertification stages with the maximum desertification rate in the end of 1980s.

In the south, in the strong, medium and moderate arid areas of Kizlyar district desertification is manifested by uncontrolled overgrazing of sand rangelands, excess cattle populations, rangeland vegetation degradation, and sand deflation.

In the east, in the strong, medium and moderate arid areas of Astrakhan district, desertification effects are evident in the Volga-Akhtuba flood plain, where xerophytization of meadows, drying of tree-scrub stands along river channels, and secondary salinization of soils, indebted by the sinking of the water level of the Volga river, pollution by irrigation waters and mineralization of ground waters. Additionally, the Volga uplands are covered by unfixed hillock sands represented by medium and moderate desertification.

In the north, in the slight and moderate arid areas of the Volgograd and Saratov districts the desertification process is demonstrated by accelerated sheet and deep soil erosion, soil dehumification and secondary salinization of abandoned irrigated soils and rangelands affected by salined and wetted discharge irrigated waters.

In the moderate and slightly arid areas of the Orenburg district the most dangerous features of desertification are the rapid degradation and dehumification of soils, a hazardous decrease of the soil depth, accelerated wind deflation of the productive soil horizon, dust storms, pronounced mineral pollution of soil, appreciable degradation of steppe vegetation, dramatic death of tree groves, and an appreciable decrease of biodiversity.

Desertification in the west Siberian-Altay province

In the west Siberian-Altay province the growth of desertification of dry humid and semi-arid areas is well known in the form of xerophytization of steppes and forest-steppes, exhausting the water supply of lakes and local rivers, drying of the pine forests and salinization of soils. The desertification effects are noticeable in the west Siberian-Altay province within the Chelyabinsk, Kurgan, Omsk, Novosibirsk and Barnaul districts.

In the moderate, slight and periodical arid areas the Chelyabinsk, Kurgan and Omsk districts are covered by dry true steppe pastures, forest-steppe patches, and dry farming lands (Krylov, 1919). Moderate desertification of these districts has long been known even at the end of the 19th century when there was extensive land development and cultivation. Recently, large industrial desertification areas appeared near urban factories (for example, Magnitogorsk, Orsk and other environs).

The best known phenomenon of boreal desertification in west Siberia is the Barabinskaya steppe, a regional model of the current dynamics. In the moderately, slightly and periodically arid Omsk and Novosibirsk districts a long-term trend of progressive xerophytization of steppe-meadow areas may be observed (Vagina, 1982). The drying of ecosystems is caused by the spontaneous lowering of groundwater level and the exudative water regime of soils. Intensive constant overgrazing of true meadows form a modification of the stepped halomorphic solonetz meadows. Over them, the wet meadows and the grass swamps turn into stepped halophytic meadows due to long-term desertification. An important indicator of desertification is a progressive drying of lakes, lowering of water levels, and salinization of drained lacustrine soils (Maximov et. al., 1979).

In the moderate, slight and periodical arid areas of the Kulundinskaya steppe in the Novosibirsk and Barnaul districts, climatic humidification in the last few decades varies in size. Currently, a decrease in land wetting and on anthropeic degradation of vegetation and soil that leads to desertification may be observed. An obvious indicator of desertification is the reduction area of pine communities and drying of tree stands.

Desertification in the Middle Siberian-Sayan province

In the medium, moderate, slight and periodical arid areas desertification may be observed in the intermountain depressions in the Kemerov, Krasnoyarsk, Minusinsk and Kyzyl districts. In the province, severe desertification is described in the Kyzyl district, where productivity of pastures dropped many times in the course of overgrazing, and medium desertification created 'isle' steppes as a result of deforestation.

In the slight and periodically arid areas of Krasnoyrsk district (Shirinskaya steppe) and Irkutsk district (Balaganskaya steppe) desertification is prevalent in the intermontane depressions. The degradation of grasslands from severe overgrazing arises from the xerophilization of vegetation and soils. This process is expressed in a decrease in biomass, oversimplification of plant communities, and destroyed succession from climax of dry steppes *Festuca pseudovina* and *Stipa capillata*, through a series of sub-desert *Cleistogenes squarrosus, Potentilla acaulis, Artemisia frigida, Thymus serphyllum* and annual wastelands plants.

The moderate, slight and periodical arid areas in the Minusinsk district are destroyed by overgrazing, forest fires, and secondary wind erosion. Furthermore, it should be added here that natural desertification is caused by chemical pollution from the giant aluminium plant, and a large area of wastelands has been formed as a result.

The medium, moderate, slight and periodically arid areas in the Kyzyl district originate the second centre of the Russian desertification (after the first,in Kalmykian, described above). The determining factor of desertification in the Kyzyl district is severe overgrazing of rangelands and degradation of vegetation and soils (Gorshkova, Shushueva, 1981). In the moderate, slight and periodic arid areas the desertification successions are similar to the above described desertification changes in the dry steppes of the Krasnoyarsk district. Here, in the course of pastoral desertification, the biomass of rangelands over the last decades drops threefold, plant projection twofold, plant density fourfold. In medium arid area the deserted steppes, due to severe overgrazing, are replaced by the sub-shrub-short grasses *Nanophyton erinaceus* and *Stipa gloreosa* and by semi-deserts with non-productive lands covering more than two-thirds of the area.

Desertification in the east Siberian-Daurian province

The desertification symptoms in the east Siberian-Daurian province are clearly evident. The substantial features are depleted ploughing, severe overgrazing and progressive deforestation. In this province the desertification impacts are observed in the moderate, slight and periodically arid areas in the Ikutsk, Ulan-Ude and Chita districts. In the south of the Chita district many mining factories produce technogenic deterioration which causes land disturbance, chemical pollution, water erosion, ground drying, outfall deflation, soil and vegetation degradation (Mikheyev, 1995; Mikheyev, Naprasnikov, 1998).

In the dry humid bioclimates of the Irkutsk district the forest/steppe localities are susceptible to local ecological disturbances. There, the overgrazed and damaged arable lands provoke land form deflation, dust storms, soil drying and organic matter depletion (Bazhenova et. al., 1995).

In the dry humid and semi-arid bioclimates of the Ulan-Ude district, desertification effects are strikingly evident in the soil and vegetation of intermontane depressions (Dambiev, Tulokhanov, 1993). There, the original tall grass and meadow steppes are now degraded by one third and replaced by secondary short grass and sub-shrub dry steppes *Aneurolepidium pseudoagropyrum, Cleistogenes squarrosus, Stipa decipiens, Potentilla acaulis* and *Artemisia frigida*. Desertification of steppe depressions is caused by the depleting effect of ploughing and, later, overgrazing. Evident desertification is especially observed in the forest xeroseries on dry quarternary alluvial sands. Here, the bare mobile sands are produced where once were stands of pine trees after heavy fire, extensive felling and severe overgrazing.

In the dry humid and semi-arid bioclimates of the Chita district the effect of desertification is evident in vegetation and soil degradation, long-term sheet soil erosion, sand deflation, overgrazing and deforestation. Degraded dry humid areas turn to short grass and sub-shrub steppes on the southern chernozem and chestnut soils. Semi-desert areas are covered by degraded haloseries of *Puccinellia tanuiflora, Alopecurus ventricosus* and *Limonium aureum* on secondary saline and solonetz chestnut soils.

The Russian concept of desertification also considers the dry cold bioclimatic arid areas, which are spread through the Yakutsk district. There, the short-grass steppes are derived from aridity on the one hand and permafrost on the other hand. From this point on we use the term 'arctic desertification' and exclude the Yakutsk district from our map of arid bioclimatic zones in southern Russia

Conclusion on development of desertification in the Russian Federation

The basic concept on desertification was posed by UNCOD (1977) and later derived in the former USSR. The Russian concept of the meaning of the term desertification contains biocentric, dynamic and economic features. This term was described as 'long-term environmental transformation of landscapes, where deserts, semi-deserts and dry lands are changed into true deserts, and short-term anthropogenic shifts, where complete and well-formed desert ecosystems are disturbed and changed into primitive systems prevailing of mineral arenas' (Vinogradov, 1976). After the formation of the Russian Federation, since 1992 the basic concept on desertification was included within the framework of the State Programme 'Ecological Safety of the Russian Federation'. At the same time desertification researches were started within the framework of the working group 'Arid Lands' in the Russian Committee of 'Man and Biosphere' (UNESCO, Moscow). The key advantages of desertification studies include zonal and regional mapping (Vinogradov, 1997b) and ecological and aerospace monitoring of desertification (Vinogradov, 1997a).

The main practical division of desertification studies is the assessment of indicators of degradation changes in southern Russia (Vinogradov, 1996). We reveal three classes of indicators of desertification disaster conditions: thematic, spatial, and dynamic. The thematic indicators consider some main groups: climatological, hydrological, geological, geomorphological, pedological, botanical, zoological and archaeological. The instantaneous or static indicators of desertification in Southern Russia can be classified in four groups: no+slight, moderate, severe, and very severe+completely destroyed (mean value in five to eight years of permanent observations on test areas not less than 10,000 to 100,000 hectares). The spatial indicators reveal local, district, and regional disaster areas ranging in extent from thousands to millions of hectares. The dynamic indicators are determined by a rate of temporal changes from stable sites with a change of less than 0.5 per cent of area per year, to catastrophic sites with a change of more than 4 per cent of area per year. Use of these biotic indicators permits the prediction of ecological disasters for five to ten years ahead and so prevent the disasters or reduce the damage from disastrous desertification. The criteria of ecologically unfavourable conditions, including desertification indicators, since 1992 were elaborated within the framework of the State Programme 'Ecological Safety of the Russian Federation' (Vinogradov, et. al., 1993) and 'Ecological Monitoring System' (Vinogradov, 1997b).

The current studies of desertification in the Russian Federation are:

1. Determination of standardised indicators of desertification phenomena, which are required for reasonable reliability and sensitivity to ecological changes in environment;
2. Monitoring of the current dynamics of desertification by long-term environmental observations and statistical data analysis, comparison of repeated spatial surveys – thematical maps, aerial and space images;
3. Revealing of discrete stages of desertification processes as derived from the study of climax and subclimax ecosystems, description of derivative ecosystems and serial successions up to full deterioration of a territory;
4. Determination of an origin of desertification processes based on experimental research in test sites and on computer machine perform, mathematical modelling, trend data analysis, and multifactor correlation;
5. Multi-scale cartography of desertification processes and indicators, and preparation of the dynamic maps at the output of the GIS;
6. Compilation of action plans to combat desertification for every geographical district within Southern Russia (as was done for Kalmykia under the support of UNEP, that was an excellent example of how it can be done (National Programme, 1995));
7. Inclusion of recommendations of regional action plans to combat desertification into the Common Governmental Ecological Monitoring System.

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Carbon Sequestration in Mediterranean Basin Drylands: Prospects and Challenges

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Climate change, global warming and carbon emissions

The Framework Convention on Climate Change (FCCC) which was signed at the Rio Earth Summit in 1992 focused attention on the need to reduce trace gas (principally carbon dioxide) emissions and mitigate the effects of global warming.

The 1997 Kyoto Summit sought pledges by signatories to reduce carbon dioxide (CO_2) emissions. In addition to reducing the rate of CO_2 emissions there is also an opportunity to sequester CO_2 in terrestrial ecosystems. Much attention has been directed toward reafforestation and other revegetation measures. Carbon sequestration in natural vegetation and soils is another important carbon sink (Squires, Glenn and Ayoub, 1997). This has considerable implication for rural lands in the European Union (EU) because agriculture in the EU is becoming ever more productive as a result of technological advances.

Surpluses of agricultural products and the high environmental cost of producing some have led, along with pressure from trading nations, to the EU embarking on a programme to reduce agricultural output. Part of this strategy involves putting land out of production (the set-aside policy). In the EU, the set-aside programme has so far been designed to reduce agricultural production (table 1) but it has implications for global efforts to mitigate the effects of global warming.

The set-aside programme has seen millions of hectares of former cropland revert to grassland, shrubland and woodland. This trend reverses centuries of land conversion in Europe (figure 1). As the lands under set-aside revert to grasslands, shrublands and woodlands (figure 2), greater quantities of C are sequestered in the above-ground biomass. The soils beneath these newer communities also can sequester C. Carbon stored in soils has a half-life which ranges from

Table 1 Set-aside of arable land in the EC under the voluntary programme to end of 1992

Member state	Land area set-aside ha	% of EC area set-aside	% of arable land
Belgium	740	0.04	0.2
Denmark	5,520	0.29	N/A
West Germany	293,384	15.38	4.1
East Germany	599,243	31.41	N/A
Greece	250	0.01	N/A
Spain	84,087	4.41	0.5
France	166,575	8.73	0.9
Ireland	1766	0.09	0.2
Italy	608.705	31.91	6.7
Luxembourg	85	0.01	0.2
Netherlands	14,606	0.77	1.7
UK	132,622	6.95	1.9

Data from CEC (1991) Agricultural Situation in the EC

Note: The post-1992 scheme has changed dramatically. At first there was a 15% set-aside then it changed to 5% and then by 1996 to10%

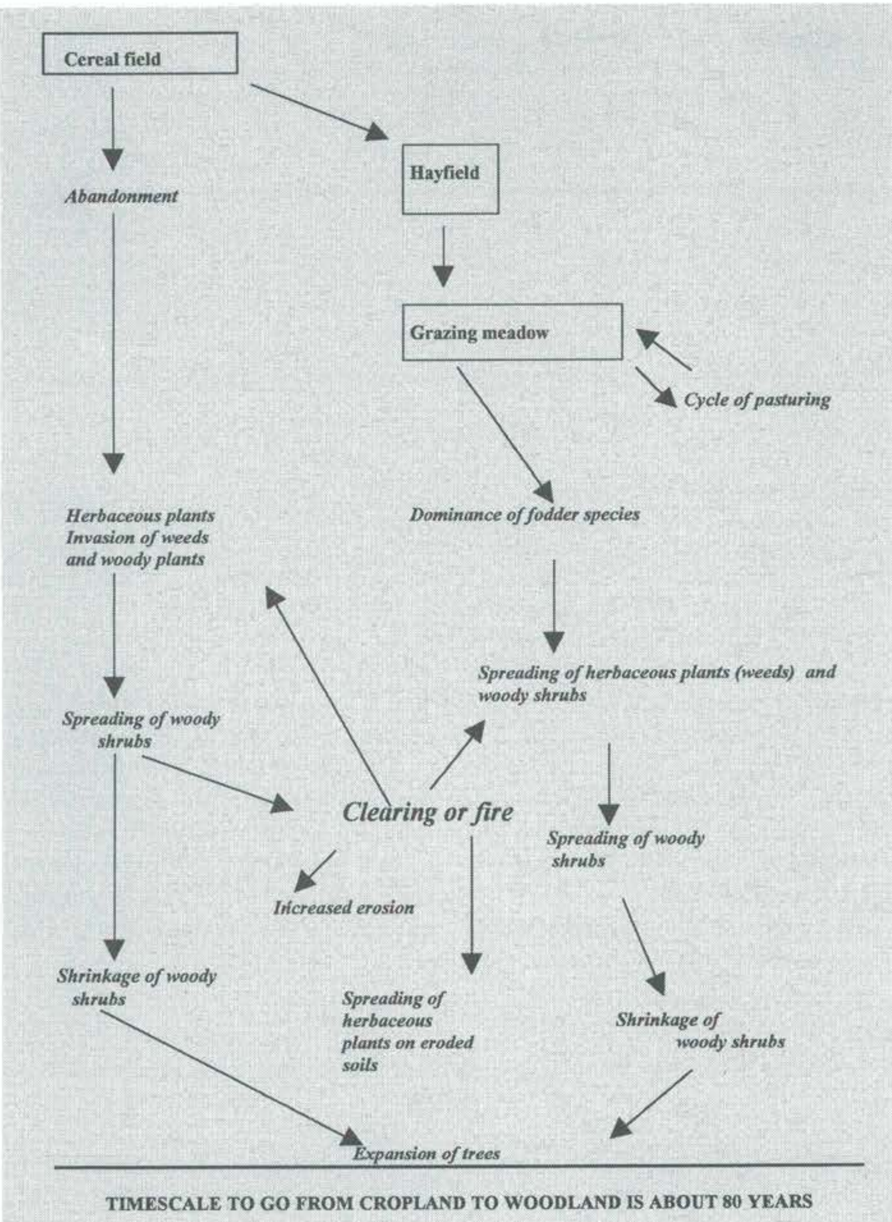

Figure 1. *Likely pattern of conversion of land for agriculture and succession after farmland abandonment in Europe.*

decades to centuries. This is particularly important in the face of rising atmospheric CO_2 levels and the projections of global climate modellers who see rising CO_2 emissions impacting on global climate until at least 2050.

Background to the current land use pattern in the EU

The intensification of agriculture in Europe that commenced in the early 1960s continued unabated until the late 1980s. This resulted from application of fertilizers, mechanization, introduction of new varieties and, above all, the expansion of irrigated agriculture. The nationally led scramble of essentially agricultural countries to participate in the global economy was fuelled and sustained in EU member countries, as it was elsewhere, by heavy subsidies for agriculture under the EU programme of agricultural self-sufficiency (Adger and Brown, 1994). The result was an over-extension into marginal lands, excessive production of unwanted agricultural goods (especially cereals) in the Union and instability in world markets as subsidised products were dumped at unrealistically low prices.

At the same time there was a continuation and acceleration of the rural exodus as urbanization took hold and as the move to the cities, or overseas as *gastarbeiten* to Germany and as economic migrants to North America. There has always been a tradition of rural out-migration in hard times, but the pace was particularly strong in the years leading to the late 1980s before return migration began to reverse the situation (Leontidou, 1996).

Coincidentally, a number of other important developments were taking place. First, the environmental movement took on political strength in many countries, though at a rate slower in the Mediterranean countries and east Europe. Secondly, the threat of global warming led to a heightened awareness of their climatic marginality. Third, a series of major droughts across the Mediterranean, especially in the early 1980s in the western sector and in the 1990s throughout the whole basin, heightened awareness of the critical condition of water resources. Fourth, a number of major floods in Mediterranean France, Spain and Italy reinforced concerns about the inherited impacts of land degradation.

There were a number of responses to these perceived threats. Reform of the agricultural policy in the past decade has involved set-aside (see below) and a range of agri-environment schemes such as the designation of Ecologically Sensitive Areas (ESAs), and of Nitrate Sensitive Areas (Dubost, 1998). These aspects will not be dealt with in the present article, but their implications which have an impact on land use practices and hence on carbon fluxes.

In the early 1990s the international community, in the General Agreement on Tariff and Trade (GATT), pressed for a relaxation of agricultural subsidies world-wide and this has been approved by the Union. As a result there has been, and continues to be, a progressive withdrawal of subsidies that is likely to level out in the next few years. Coupled with this, under the MacSharry proposals, there is an effort to accompany the reduction in subsidies with specific environmental

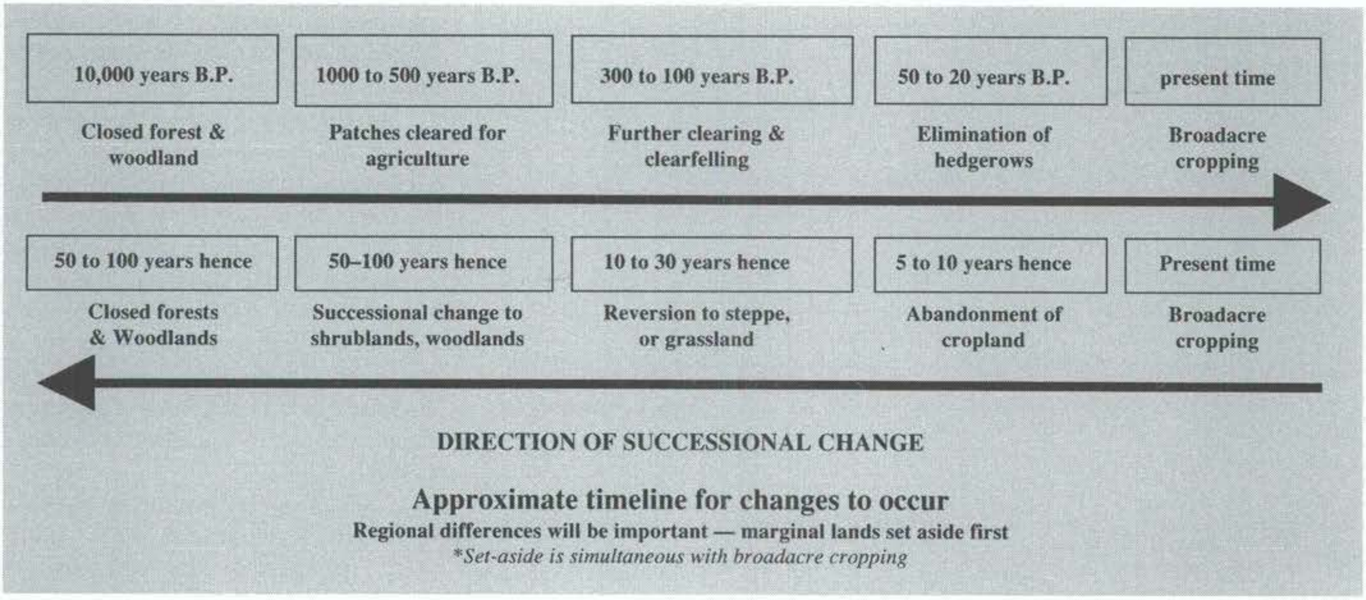

Figure 2. *Evolution of abandoned agricultural fields in southern Europe (after Molinillo et. al., 1997, redrawn).*

measures. One of these measures was to voluntarily retire cropland from cultivation (set-aside). This policy allowed farmers to receive payments in lieu of foregone production. The policy has undergone some changes over the past decade. There was voluntary set-aside prior to 1992 but the post-1992 scheme has changed dramatically; first of all with 15 per cent set-aside them moving back to 5 per cent then 10 per cent of the arable area by 1996.

Initially farmers are not allowed to claim subsidies unless 15 per cent of their arable land was set-aside from agricultural use. In reality farmers set-aside land of poorest quality so that the economic aims are not being satisfied, while farmers in northern Europe claim that to recover this land in the future will be very costly. In the Mediterranean basin lands, forecasts show a more or less continuous decline in upland agriculture for the foreseeable future (Brandt, 1995). It follows that to be paid to abandon land is a positive incentive. If at the same time a carbon dividend can be provided, then the prospects both for carbon sequestration and land management are positive. The regulations on set-aside are the key to understanding the carbon fluxes. During the 1990s the scheme moved from only allowing rotational set-aside (with no significant build-up of biomass or soil carbon) to allowing afforestation on such land. This latter change is having the most profound impact on soil (and above-ground biomass) carbon. In addition, all countries of the EU have national land-use policies, particularly as they relate to forestry, which also have an impact on carbon pools.

Although voluntary set-aside predates GATT it was given teeth in the 1992 agricultural reforms. Whilst its objective is primarily to reduce over-production, and although it is only partially effective in this, it coincides with the abandonment of land in southern and middle Europe and is in a direction that should reduce the offsite impacts of further land degradation.

Table 2. Carbon content of selected soils in eastern Europe, and Australia*

Soil type	Location	Rainfall mm/yr	Total carbon* %	Depth of horizon cm
Brown-gray podzolic	Poland	550-560 A	A 2.53	0-20
			B 0.21	B 45-55
Loamy glacial drift	Poland	598	A 1.21	A 0-45
			B trace	B 45-95
Rendzina	Poland	620	A 3.03	A 0-50
			B nil	B absent
Red-brown earth	Australia	550	A 1.2	A 0-12
			B 0.3	B 13-45
Grey clay	Australia	425	A 0.9	A 0-12
			B trace	B 13-50

Organic carbon only — excludes $CaCO_3$

Future options for rural land use in the EU

The EU have considered future options for rural areas to 2015. These are summarized in table 3. Compared with the baseline year (1992) reduction in the area of land under crop could be as high as 50 to 100 per cent. Of course there will be regional differences. Environmental concerns and the actions of GATT will cause increasing land surpluses, irrespective of policy. This will lead to massive increases in the land set aside. Set-aside land is a potential sink for considerable amounts of C. Just how much will depend on future management, prevention of wildfires, especially in the Mediterranean basin, and indiscriminate clearing of woodlands and forests.

Table 3. Four Scenarios for Agriculture and Forestry up to 2015 in the rural areas of the EU

	1992*	2015				REDUCTION
		A	B	C	D	
LAND USE M.ha	127.0	42.2	76.8	26.4	60.7	-50 to-100%
EMPLOYMENT m..mpu #	6.0	1.5	2.2	1.8	2.2	-3.0 to 4.5
NITROGEN USE m.tonnes	11.0	2.1	2.8	2.1	2.1	8.2 to 8.9
PESTICIDES m.kg	40.0	60.0	89.1	21.2	33.0	-50 to+50%

Key to scenarios
A Free market and free trade
B Regional development
C Nature conservation and landscape diversity
D Environmental Protection (pollution control)
 # Manpower units

Source: Netherlands Society for Govt. Policy Report no.42 1992

Given the history described above, there is evidently a need to consider the following questions:

i. What is the nature of the land degradation problem in Europe, especially eastern and southern Europe?
ii. What is the likely impact of global warming on the problem?
iii. How should it be approached through national and Union action?

By coincidence the recognition of the problem, the changes in agricultural policy and the opportunity to offset global warming by carbon sequestration, seem to converge on revegetation as the obvious mechanism to achieve this.

Land use change and carbon flux

This section examines some implications of the recent policy shifts of the European Union as it relates to land use and, in particular, considers the likely consequences of the set-aside and other land reversion schemes to carbon sequestration in those countries.

As suggested by Adger and Brown (1994) land-use change alone cannot provide the sole mechanism for offsetting the carbon releases, even of the low energy consumption nations of eastern and southern Europe. But, in parts of the EU, there is the chance of a double or even triple benefit. There is a co-occurrence of favourable events. Although land continues to be degraded, other land is being abandoned or retired from cropping at a time when subsidies are available for environmental action, much of which represents good land management. Carbon sequestration, coupled with erosion mitigation, associated water conservation and flood reduction seems to offer a possible solution to the land degradation problem.

Land abandonment, long fallow, the shift from the countryside and the decrease in agricultural subsidies following the GATT agreement means that the returns from poorer quality land (that most common in the dry areas) are falling, a trend that seems likely to be sustained, at least on the poorest land.

As a consequence, land management policies, including set-aside and the actions accompanying the GATT agreement outcome, are being developed to shift the land use from production to conservation. Under these circumstances, although carbon sequestration is not the prime cause of land reversion from tillage to shrubland and/or woodland, it could be a significant added value that could substantiate the argument for allowing this policy to continue and even to encourage it. The carbon gains so achieved, at low or zero cost, could be used to offset carbon dioxide production from the eastern European and Mediterranean countries. It could attract investment, from highly industrialised countries, in land management, fire control or establishment of recreational facilities. Even better, those offsets could be more directly used to apply specific erosion control measures.

Managing soil for carbon storage

Generally, soil organic carbon (SOC) levels in many European soils are high, especially in relation to cropland soils in the New World (table 2). Schlesinger (1984) estimated that 7.9 kg m^2 of carbon was stored in agricultural soils in temperate regions while Buringh (1984) assumed 9.5 kg m^2 for temperate zone cropland and 11.6 kg m^2 for grassland.

This high level of SOC may limit the capacity to sequester more carbon into the soil organic matter pool (Cole et. al., 1993) although Sauerbeck (1993) postulates that under optimum soil management it might be feasible to increase the carbon level of existing arable soils in the temperate zones by up to 1 kg m^2. It could take 50 to 100 years to reach this new level of SOC. Cole et. al., (1993) estimate that such a change in SOC status of the 690 x 10^6 ha of arable lands would sequester in the order of 6.2 Gt of carbon over the 50 to 100 year period. The key is good soil management.

Soil management practices have significant effects both on the rate and extent of soil organic matter decline and on restoration of SOC levels. Organic carbon is most rapidly lost within just a few years of land conversion from forest or grassland to cropland, but the reverse process is slower. The reversion of cropland to pasture and woodland or forest is one way to ensure that carbon sequestration is enhanced. On many sites, though, the process of natural regeneration is too slow. Revegetation is essential and human intervention is the norm (Allen, 1995). Little additional SOC could be stored unless a new set of management practices is initiated. Arguments about the specific net benefits of carbon sequestration in former cropland are dependent on a detailed economic, social and cultural analysis of the costs and benefits. Moreover, they are very sensitive to:

- discounting rates;
- areas under transformation;
- actual estimates of carbon captured;
- mass of below-ground biomass;
- mass of undecomposed litter;
- initial soil organic carbon content;
- rate of biomass production.

Future carbon fluxes in agro-ecosytems of southern Europe

For analysis of future carbon fluxes the primary focus needs to be on current changes in land use and management as well as future adjustments in management when agricultural communities respond to climate change and to policy shifts. In many areas the set-aside land is reverting to woodland or to scrub-forest. No up-to-date estimate is available for the whole of the EU and the estimates of the carbon pools are still tentative.

Work in the Mediterranean Basin indicates that the increase in organic matter with length of time since abandonment is not necessarily associated with an increase in infiltration rates (Brandt, 1995). Abandonment after tillage can lead to an overall increase in bulk density and effect gully head development (Oostwoud Wijdenes et. al., 1998; Ruiz-Flano et. al., 1991). And, in the long term, if bush vegetation establishes and stabilizes there can be an increase in runoff due to the reduction in annuals which were now unable to compete. Often under woody vegetation there is an absence of a field layer.

As far as southern Europe, especially the Mediterranean region, is concerned the prospect of restoring the lands to their original ecosystem may be neither desirable nor practicable. At the same time there is little likelihood that the mountain lands will ever be in great demand for agriculture (Molinillo et. al., 1997). The clocks are unlikely to be turned back again despite the traditional use of the land as the buffer against hard times in the Mediterranean. On the other hand, the heavily degraded land (where foliage cover is very low) enhances runoff and flooding, and sediment yield and reservoir siltation and other off-site effects (Garcia-Ruiz et. al., 1995). It seems to follow that, in the most degraded land at least, revegetation as a form of rehabilitation or reallocation should have a high priority.

The immediate need is to ensure the conservation of water resource, to limit flooding and to prevent reservoir siltation. At the same time there is the prospect of multiple benefits. These include recreation, progressive soil improvement, a nutrient bank for the future and, of course, the possibility for carbon sequestration. Therefore in this context of net gain we have to see carbon sequestration as part of a package of benefits, in working out its overall potential. Moreover, we have to reckon with the existence of potentially multiple stable states and thresholds of stability without calling for restoration of the original ecosystems. Modern ecosystems theory does not allow the luxury of an ultimate stable state or goal to which the system is operating but does provide us with non-linearities that have to be known and manoeuvred to our benefit (Westoby and others, 1989; Walker, 1993).

Response of woody plants and self-regenerating annuals to climate change

Woodward and Diamond (1996) have compared the response of shrubs and annual herbs to a 1.5°C increase in temperature and a 15 per cent fall in precipitation. This shows, for Spain, nearly parallel changes in shrubs and grasses, a stronger impact in drier areas (as a percentage) and only a small absolute effect in areas with less than four dry months per year. Similar results were obtained by Kirkby and Neale (1986). It appears that it is in the truly dry environments of the Mediterranean, where the seasonal component of rainfall is strongest, the effects of change are likely to be significant for plant production.

The prospects for reclamation

The modelling of Obando and Thornes (pers. com.) of abandoned land recuperation and its impact on erosion, shows that recovery rates and character are heavily dependent on rainfall history in time and on the pattern of abandonment in space. It matters greatly to sediment yield and runoff whether abandonment is in a wet or dry spell and whether it is in the upper or lower part of a catchment, for example. This has to be considered as we develop mitigation strategies from first principles or extrapolate them from empirical results of past practices.

Constraints

The main constraints in the Mediterranean on land reclamation are water availability, grazing, fire and the level and nature of incentives. Biomass production in the dry lands of the Mediterranean depend on water (Le Houerou and Hoste 1977; Thomas and Squires, 1992). Under unconstrained growth with adequate water (say the average of 300 mm) forbs, grasses and bushes can accumulate to a 30 per cent cover at most sites in about three to four years and provide a full bush cover with typically about 3 kg m^{-2} in about 12 years in the driest lands of south-east Spain (provided that there is some soil left in which seeds can establish). This is without the application of fertilizers, water or even management.

The future prospects for increasing the level of biomass will depend on the likely shifts in rainfall belts, and the prospects are not good. Climate change studies suggest that rainfall could become less, temperatures higher and rainfall more intense (Pausas, 1998). So that net primary productivity, which is closely coupled to rainfall, is excepted to fall relatively, marginally in the wetter regions and significantly in the drier areas.

Management of any enhanced biomass is required because

(a) the fire risk increases with the mass of standing dead material (Specht, 1981) and any increase in fire frequency or severity is both a perceived and real hazard throughout the Union nations of the northern Mediterranean, for a variety of complex reasons;
(b) it is practically difficult to inhibit grazing now, especially since new subsidies in 1995 have seen a rise in sheep populations (Dubost, 1998). The pattern of herding is changing. The distribution of herding sheep and goats over the canadas (long transhumance routes in Spain), for example, has almost entirely died out.

The role of grazing itself is somewhat problematical. Studies in Nios (Margaris, 1995) show that the major impact of grazing is to increase fire. As the pressure increases the available standing crop decreases and pastoralists set fires to encourage young growth. Others (Papanastasis and Peter, 1998) have claimed that maintaining grazing will be necessary to control the likelihood of fire by reducing the amount of standing dead. Grazing exclusion experiments in Lesbos (Greece) showed an increase in cover, diversity of woody species, absolute number of plants within the exclosure and, sometimes, substantial reductions in erosion rates without grazing (Brandt, 1995).

It may be far cheaper to provide feed for the animals and reduce fires, allowing grazing to continue, than to expend money either on a fire-fighting service or stopping grazing and importing food from other regions. The prospects for removing the grazing constraint depends, therefore, on the development of alternative strategies for fire management.

The third constraint is the question of incentives. Unless financial incentives are provided the management of land will not take place. Payment to land holders to abandon cropland is a positive incentive and farmers are responding. If, at the same time, a carbon dividend can be provided, then the prospects both for carbon sequestration and land management are positive. There are social, political and economic benefits to the EU countries which need to be elaborated more fully after further research.

Discussion and Conclusions

The following observations can be drawn from what has been said above:

1. That the European environment (from the northern Mediterranean lands to the margins of the forest in the north) is very complex in space, has had a complex cultural history and has a rainfall that is highly variable in space and time. Under these circumstances sweeping statements about the potential for carbon sequestration and its advantages are to be treated with circumspection and even scepticism. But data from the MEDALUS project (Brandt, 1995) show that with a fully developed bush cover, under present conditions, first indications are that the benefit will be significant, and of the order of 4 to 6 tonnes/ha in successful years;
2. Unfortunately the indications from the MEDALUS climate change studies (Brandt, 1995) suggest that rainfall could become less, temperatures higher and rainfall more intense, so that net primary productivity, which is closely coupled to rainfall (Le Houerou and Hoste, 1978; Thomas and Squires 1982) is expected to fall relatively, marginally in the wetter areas and significantly in the drier areas. Also the indications are that the doubling of CO_2 will not notably increase production;
3. The general balance, therefore, seems to be that the prospects for sequestration are good from a social, political and economic point of view, even if the action is only to leave the abandoned land in scrub. However, the coupling of productivity to rainfall means that the uncertainty in quantity of sequestered carbon will be high and the long term climatic prospect is for a worsening of the average productivity in the lands most in need of reclamation;
4. Sequestration should probably, therefore, be viewed as an important desirable beneficial output of contemporary desertification mitigation policy and action rather than an ultimate goal in its own right in these environments and under current cultural, political and socio-economic and future climatic conditions. This view may need to be revised as more data becomes available, but on its own, carbon sequestration is unlikely to be a solution to the problems of land degradation in southern Europe but the prospects in the wetter regions further north might be better.

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Salt-affected Soils of the Nile Higher Terraces and Traditional Reclamation in Northern Sudan

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Abstract

Extensive salt-affected soils occur in the hyper-arid and arid zones of the Sudan, mainly in the old alluvial sediments of the Nile higher terraces. This study was carried out with the objective of determining the morphological, physical, chemical properties and classification of two soil series, Akkad and Binna, in Northern Sudan. The farmers' practice for reclaiming these two series is also considered. The two soil series have a narrow dispersed horizon of accumulated soluble salts in the root zone. Both series contain smectitic clay minerals, but Binna has mixed minerals. Akkad has a clayey texture while Binna is a clay loam, giving a relatively higher infiltration rate than in Akkad. Chemically, both series are saline, whereas Akkad is more sodic than Binna. Both soil series have similar soil classification down to the subgroup level as Natric Camborthids, but differ at the family level with respect to the mineralogy. In order to cultivate these soils the farmers use traditional ploughing, levelling and farmyard manure with frequent flooding irrigation. This practice significantly reducesthe salinity, but has minor effects on the sodicity. It is proposed that further investigations are needed for the improvement of the current farmers' traditional reclamation, especially with respect to soil sodicity.

Introduction

Salinity is a widespread problem in the hyper-arid and arid zones, where evaporation potential is high and rainfall is not sufficient to leach the salts from the soils. Irrigated agriculture has faced challenges of sustaining its productivity for centuries, due to the excess of salts in the root zone caused by many factors (Tanji, 1990). Both salinization and sodification have been identified as processes of land degradation, affecting the physiochemical properties of the soil, which drastically reduce plant growth and eventually lead to desertification (FAO, UNEP and UNESCO, 1979). Nearly 10 per cent of the world's total land is estimated to be significantly affected by salts; limiting its utilization for crop production in at least 75 countries (Szaboles, 1985; Rhoades, 1990). On the other hand, about 30 per cent of the irrigated land in the world is seriously affected by salt, decreasing its productivity, and threatening the economy of many of the arid countries, such as Egypt, Iraq and Pakistan (Rhoades, 1990).

In the Sudan systematic soil surveys revealed only small portions of the total salt- affected areas. More extensive salt-affected soils occur in the hyper-arid and arid zones, mainly in the old alluvial sediments of the Nile, White and Blue Niles. The locations of the salt-affected areas are mainly in north-western Gezira and the Managel Scheme; the higher terraces of the White Nile; the vicinity of the confluence of the Blue and White Niles and along the River Nile northwards on its higher terraces (fig 1). The degree of salinity increases with the increase of aridity in the country from latitude 13∞ to 22∞N. The total area surveyed along the Nile is about 200,000 ha, where 68 per cent is affected by salts (Nachtergaele, 1976). Beside the surveyed areas, there are still extensive areas which are potentially vulnerable and, under irrigation, could easily be damaged by salinity and/or sodicity, unless reclamation programmes are considered.

Recently, current agricultural policy focuses on irrigated land to attain high food production for self-sufficiency, to mitigate the effects of drought and to bridge the food shortage gap, especially of wheat. The Northern State (fig 1) of the Sudan has, relatively, the most optimum temperatures during the winter season (November to March) for wheat, legumes and spices production. Thus the increasing demand for food and the scarcity of suitable arable lands, which are already

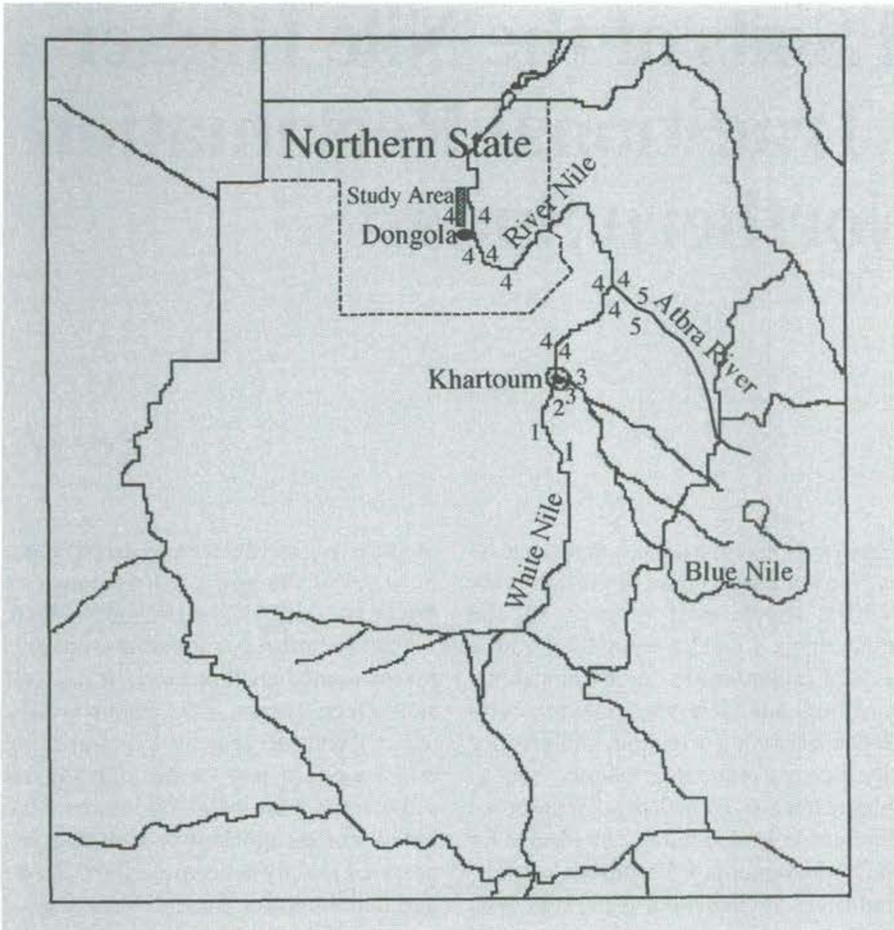

Figure 1. *Locations of salf-affected soils in the Sudan. 1-White Nile terraces. 2-North-West Gezira & Managel. 3-Vicinity of Khartoum. 4-River Nile higher terraces. 5-Atbara River terraces.*

fully utilized in the Northern State, necessitate the urgent need to develop the marginal lands, which are often salt-affected soils.

The main objectives of this study were:

1. To characterise and classify the soils of the Akkad-Binna Project in the Northern State;
2. To study the behaviour of the soils of the project under saline-sodic conditions;
3. To assess the management practices of the local farmers towards the salt-affected soils (conventional reclamation).

Materials and methods

Study area

The study area lies on the western bank of the Nile about 40 km north of Dongola, the capital of Northern State. It is enclosed between latitude 19∞ 30' and 19∞ 42' N, and longitudes 30∞ 21' and 30∞ 24' E (fig 1). The climate is hyper-arid characterized by the scarcity, variability and unreliability of rainfall (< 50 mm/ annum) accompanied by high evapotranspiration. The moisture regime reveals a continuous water deficit throughout the year (fig 2). The lowest monthly mean temperature recorded is 6.5∞C in February and the highest 45.2∞C in June (Van der Kevie, 1973). The area has two seasons only, a cool winter from November to March and a hot summer from April to October. The summer is very hot and dry because south-westerly winds do not bring rains to the region except rarely in July and August. The winter is characterized by strong dry north-easterly winds, which cause serious sand drifts. The Nile and the agricultural lands of the recent terraces along it with settlements protect the Akkad plain from wind erosion. The area is bare with no natural vegetation except along the few natural drains, where some trees, sallum (Acacia ehrenbergiana), are scattered. The soils in the study area were developed in parent materials, which had been deposited by the River Nile in the recent Quaternary period. They occupy a higher landscape compared to the present flood plain (fig 3). The thickness of the Nile deposits varies from 3 to 5 metres, underlain by sand and gravel of 1 to 2 metres resting on fine-grained Nubian sandstone of the lower Cretaceous period (fig 4). There are three sources of irrigation water in the area: the Nile, deep-bore wells and shallow wells. The groundwater tapped from the Nubian sandstone aquifer underlines that the Dongola area is of excellent quality having low amounts (90 ppm) of dissolved salts (Iskanderd, 1985). Also, the water of the Nile is of excellent quality (Beam, 1908; Jewitt, 1955). Based on SAR and EC (US Salinity Laboratory Classification), the water quality of the Blue and White Niles are of excellent quality (C1S1), but the White Nile is C2S1 during its low level, March to May (Mustafa, 1973). The main winter crops are wheat, legumes and vegetables, while the main summer crop is sorghum. The perennial trees are mainly date palms and citrus with alfalfa.

The soil data were collected from two sites in the Akkad plain representing the Akkad and Binna series (Fadul, 1978). Six sites were selected from cultivated land and its adjacent virgin for auger sampling for both series.

Methods

Two profiles were dug to a depth of 1.5 m in the Akkad series and 1.75 m in the Binna series. The profiles were described following the standard format of FAO Guide Lines (FAO, 1968) and classified according to Keys of Soil Taxonomy (1994). Auger samples were collected at depths 0 to 30, 30 to 60 and 60 to 90 cm. At the sites of the profiles, the infiltration rate was measured in three replicates using the double ring method (Bouwer, 1986). The samples were collected genetically from the profiles for physical and chemical analysis. The samples were collected by

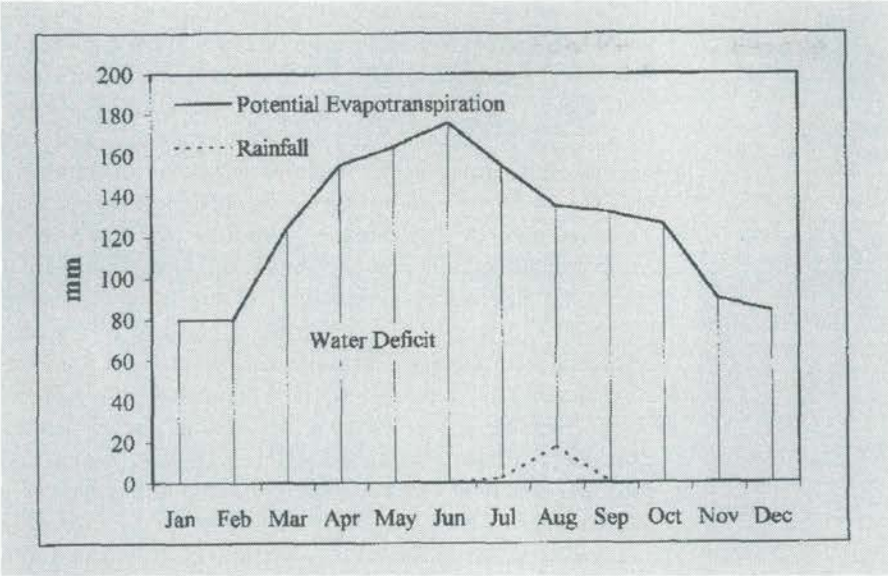

Fig. 2. Water balance of Dongola area as indicated by the average monthly rainfall and potential evapotransportation.

auger for determination of EC, exchangeable Na^+ and cation exchange capacity (CEC), in order to compute ESP. All results of the analysis refer to oven-dry soil and sieved through a 2 mm sieve. Particle size distribution was determined by a pipette method (Day, 1965). Soil pH was measured on 1:1 soil:water extract (Mclean, 1982). Soluble salts were determined by measuring EC of 1:1 soil extracts (Rhoades, 1982). $CaCO_3$ equivalent values were obtained using the acid neutralization method (Richard, 1954). Organic carbon (O.C.) percent was determined using the Walkely-Black method (Jackson, 1965). Total nitrogen percentage was determined using the Kjeldahl method (Bremener, 1960). Cation exchange capacity (CEC) was determined by using the Polemio and Rhoades (1977) method for arid land soils. The soluble cations and anions were determined by the titration method (Rhoades, 1982). Thereafter, the sodium adsorption ratio (SAR) and exchangeable sodium per cent (ESP) were computed. The hydraulic conductivity was determined by the constant head method (Klute and Dirksen, 1986).

Results and Discussion

Soil description

The semi-detailed soil survey of the proposed Akkad-Binna Project revealed that the Akkad series is very extensive and the Binna series is of minor extent (Fadul, 1978). The geomorphology of the area consists mainly of two geomorphic units, namely the recent flood plain, which contains the recent terraces (entisols) and the basins (vertisols). The other geomorphic unit is the higher flood plain (aridsols) known as higher terrace (fig 3). These soils are deep, with a narrow horizon of salts accumulation at the topsoil (25 to 30 cm). The soil colour is generally greyish brown (10YR5/2) indicating low organic matter. These characteristics reflect the hyper-arid climate (fig 2) and sparse vegetation. These are desert soils with various degrees of profile development, containing soluble salts in sufficient quantities. Differences among the soils are mainly due to sedimentation processes that give rise to textural and small topographic differences.

The potential causes of salinity occur either naturally or develop from runoff, shallow saline water-table, irrigation or

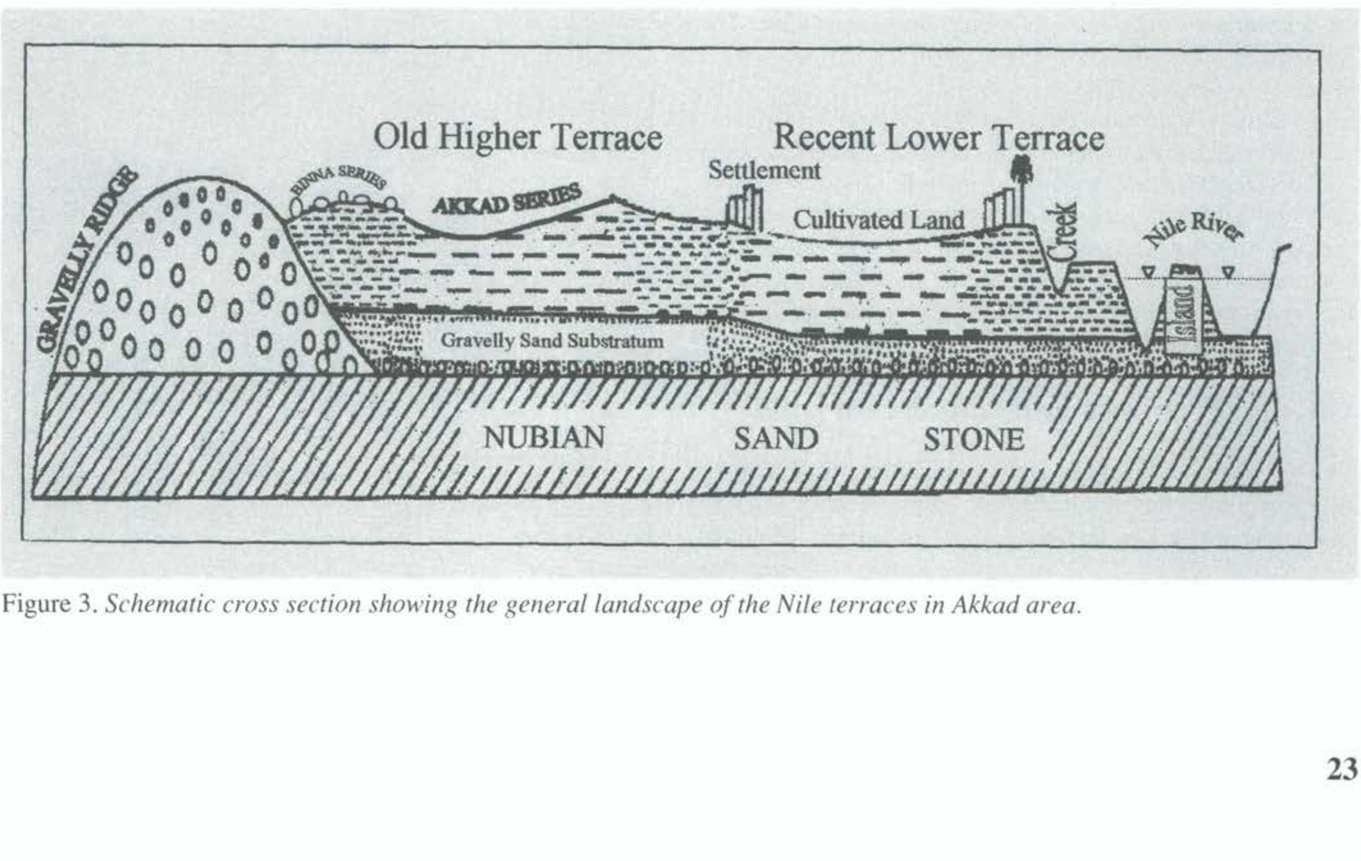

Figure 3. *Schematic cross section showing the general landscape of the Nile terraces in Akkad area.*

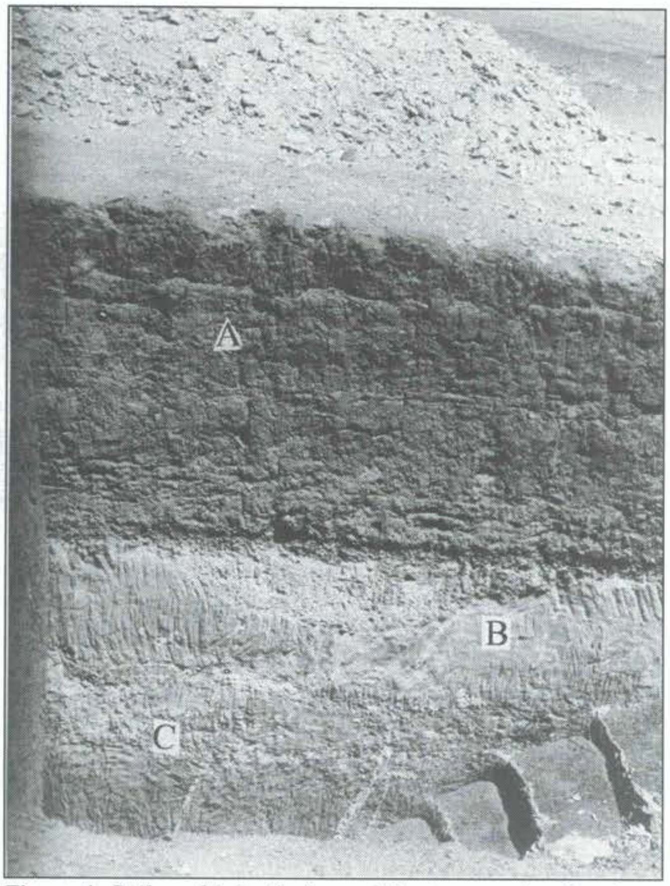

Figure 4. *Soil profile in the lower Nile terrace showing the Nile alluvial deposits (A), on sandy substratum (B), resting on fine-grained Nubian sandstone (C).*

other activities (Rhoades, 1990). The salinity in the studied area has occurred naturally, that is, inherited in the parent materials. The soils were developed in the old sediments of the Nile, derived from basaltic igneous rocks of the Ethiopian highlands (Buurisink, 1971; Fadul, 1976). The occurrence of other sources as origin for salts is far from consideration. The runoff is very limited due to the scarcity of rain and the adjacent higher areas are non-saline Nubian sandstone (fig 3 & 4). The water-table is deep, more than 6 metres as observed from the scattered shallow wells dug by the farmers. The aridity of the climate, characterized by scarcity, variability and unreliability of rainfall with high potential evapotranspirtaion (fig 2) affect the soil solution and salt balance of the soil under such conditions (Mashali, 1991). Thus the hyper-aridity of the region promotes the upward movement of salt solution to precipitate and concentrate soluble salts in the topsoil.

Effects of salinity and sodicity on soils

The processes of salinization and sodification lead to deterioration of the morphological, physical, chemical and biological properties depriving the land of its economic productivity (CCD, 1995). According to this statement, the effects of salinity and sodicity on the soils of the study area are presented.

Morphology. The morphological studies of the profiles revealed a narrow topsoil horizon of 25 to 30 cm thick in the Akkad and Binna series. This horizon has a dispersed structure with loose consistency, indicating accumulation of soluble salts (fig 5). The granular structure is underlain by a moderate medium subangular blocky horizon, which has an extremely hard consistency when dry; very sticky and plastic when wet. This consistency indicates less soluble salts and more exchangeable sodium. Few to common slip faces, fine internal cracks and slickensides were described in the subsoil indicating the swell-shrink processes of smectite clays, which hinder permeability and aeration. Smectite, which is the most dominant clay in arid and semi-arid zones, is the most active in the physiochemical processes such as swelling and dispersion (Shainberg, 1990). Clay swelling is a continuous process that proceeds slowly as the soil solution concentration decreases (Keren and Singer, 1988). The swelling of clays narrows the conducting pores of the soils (Mclean and Coleman, 1966; Quirk and Scholfield, 1955). Some spots of bare thin surface crust were also observed in the cultivated plots (fig 6). The crust formation is due to a breakdown of the soil aggregates caused by physiochemical dispersion of clays, forming a skin seal at the soil surface (Mclntyre, 1958). Accumulations of CaCO3 and CaSO4 (gypsum) in needle form were observed in the deeper subsoil of the Akkad series and only $CaCO_3$ accumulation in the Binna series.

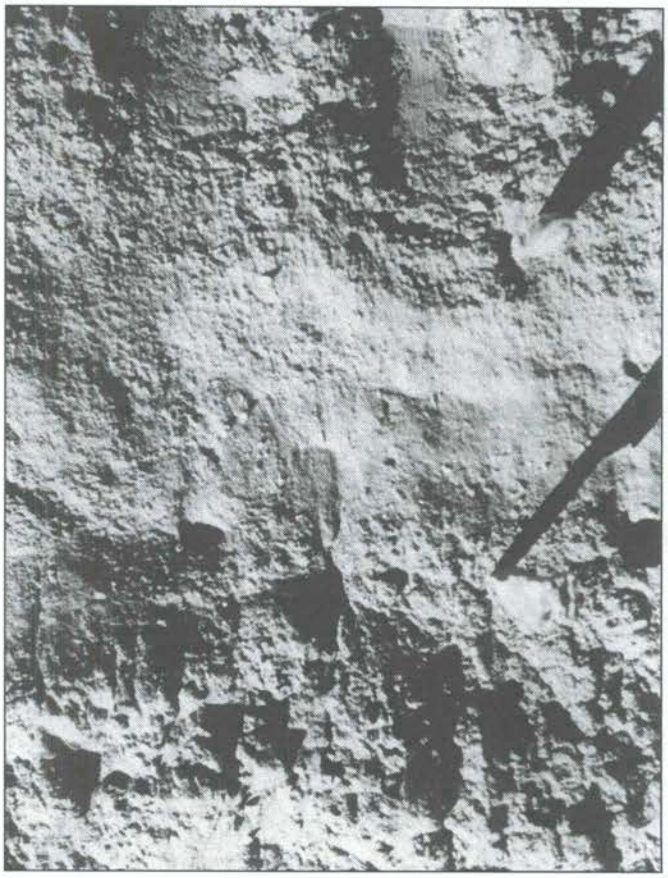

Figure 5. *Soil profile of Akkad series showing a narrow horizon of granular structure with loose consistency in the root zone with salt accumulation.*

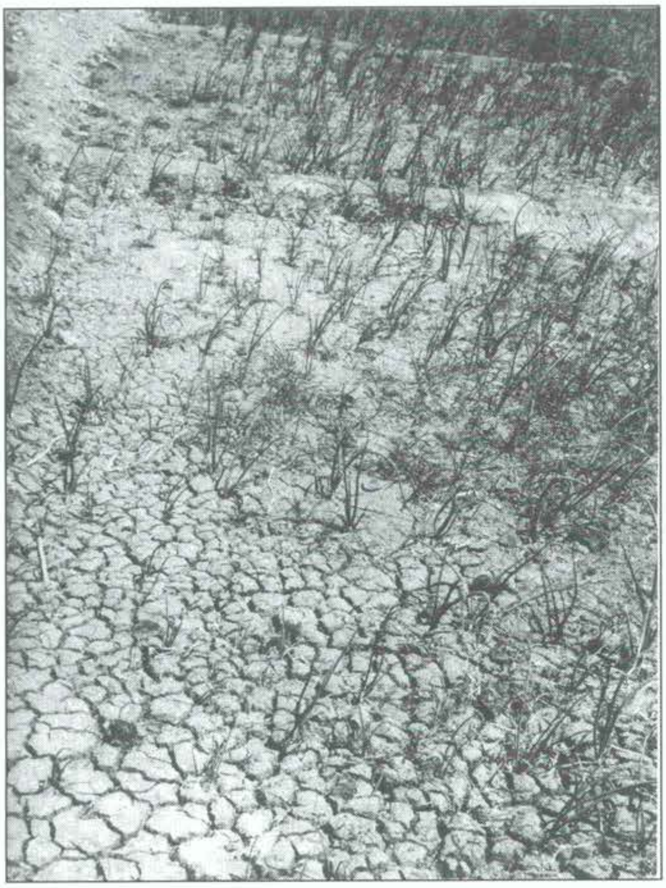

Figure 6. *Surface crusting in Akkad series restricting plant emergence.*

Chemical and physical data. The laboratory data in table 1 for the Akkad and Binna series indicate that salinity and sodicity affect both soils. In the Akkad series the dominant soluble cation is Na^+, and in the Binna series both Na^+ and Ca^{2+} are dominant in equal proportions. The dominant anions are Cl^- and SO_4^{-2} in both series, while HCO_3^- and CO_3^{-2} are negligible. The ESP in both series is higher than 15 per cent indicating the sodicity of the soils. The EC_e ranges between 23 to 27 dS/m in both soils. According to the US Salinity Laboratory (1954), these soils can be termed as saline-sodic soils due to the high salinity and moderate sodicity with pH paste less than 8.5. This high salinity and moderate sodicity has adverse impacts on the soils as well as on plants. The chemical data revealed that both soils have low organic carbon less than 0.3 per cent and clay content ranging from 35 to 50 per cent in the upper subsoil. The response of soils to saline-sodic conditions depends on the type of clay, amount of clay and the presence of binding materials such as organic matter and oxides. Stainberg (1990) stated that soils with more than 15 per cent clay and organic carbon less than 1.5 per cent have higher potential for soil sealing and crusting. In the Akkad series, the ratio of clay to CEC is 1:1, indicating that the type of clay is smectite, which is supported by the existence of the slickensides, slip faces and cracking. The high smectitic clay with low organic carbon and sodicity are favourable conditions for adverse physical properties such as crusting, slaking of aggregates, dispersion of clay minerals and swelling leading to poor tilth (Stainberg, 1990).

The textural class is a determining factor in soil reclamation. The results of particle size distribution revealed that the Binna series has more sand than the Akkad series (table 2). The increase of sand in Binna is due to its past textural sedimentation and to the addition of sands from the adjacent gravelly ridges, especially in the topsoil. The Akkad series has a high silt and clay content reducing its permeability. The infiltration rate showed that Akkad is moderately slow while Binna is moderate (fig 7). The accumulated water intake indicated that Binna could absorb more water than Akkad over five hours. The wetting front is deeper in Binna (27.5 cm) than in Akkad (24 cm). The hydraulic conductivity of Binna is moderate (3.9 cm/h), while that of Akkad is slow (1.6 cm/h). This indicated that Binna has better permeability than Akkad. It is clear that Akkad has more adverse physical characteristics than the Binna series, due to the high smectitic clay per cent and more exchangeable sodium. The high sodium level and the high pH (table 1) in Akkad lowered the permeability and decreased the infiltration capacity through the swelling and dispersion of clays and deflocculation of aggregates in Akkad more than in Binna. Squares et. al., (1984) found that hydraulic conductivity of montmorillonite and koalinite soils at pH 9.0 was lower than at pH 6.0. They concluded that differences in hydraulic conductivity resulted primarily from changes in dispersive

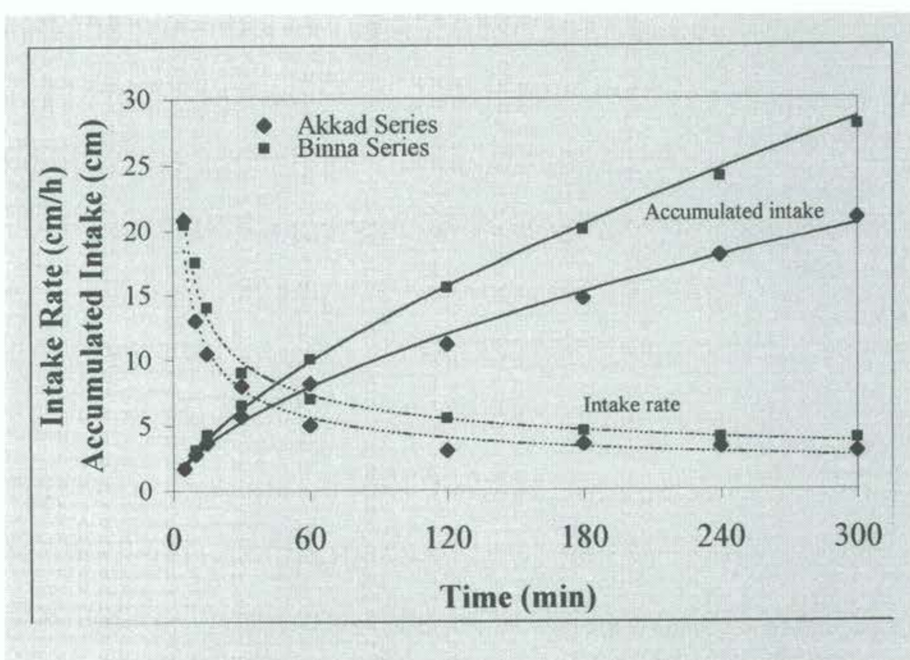

Figure 7. *Infiltration rate and accumulative intake of Akkad and Binna series.*

Table 1. Chemical data for the soil profiles of Akkad and Binna series

Soil Depth (cm)	Exchangeable Cations Na	K	CEC* (meq/ 100g)	$CaCO_3$ (%)	pH paste	N (%)	O.C.* (%)	C/N*
Akkad Series								
0-5	7.5	0.8	39	3.1	8.5	0.050	0.177	2
5-30	14.9	0.7	44	2.2	8.3	0.054	0.190	3
30-45	9.0	0.5	48	2.3	7.5	0.045	0.266	6
45-70	9.4	0.6	51	2.1	7.7	0.045	0.177	3
70-105	6.8	0.5	47	2.3	8.1	-	-	-
105-135	3.2	0.6	48	2.6	8.0	-	-	-
Binna Series								
0-8	2.0	1.1	25	6.0	8.3	0.013	0.156	12
8-15	6.8	1.6	35	3.0	8.2	0.020	0.156	8
15-25	5.1	0.8	36	3.0	7.7	0.017	0.156	9
25-40	4.1	0.8	36	4.0	7.7	0.017	0.156	9
40-95	9.7	0.7	34	4.0	7.9	0.019	0.117	6
95-135	4.1	0.7	39	2.0	7.9	-	-	-
135-175	4.1	0.6	40	5.0	7.9	-	-	-

Soluble Cations and Anions (meq/l in saturation extract)

Soil Depth (cm)	Na	Ca	Mg	Cl	SO_4	HCO_3	CO3	EC (dS/m)	SAR	ESP*
Akkad Series										
0-5	37	12	2	7	32	1.6	0.6	3.7	14	19
5-30	204	27	6	55	180	1.0	0.2	23.0	50	34
30-45	132	96	23	113	137	1.0	0.0	25	17	19
45-70	56	29	8	33	55	1.0	0.4	7.3	13	18
70-105	57	8	3	5	61	1.6	0.4	3.3	25	14
105-135	72	14	6.	2	88	1.5	0.4	4.9	23	7
Binna Series										
0-8	5	2	1	1	4	2.2	0.4	0.5	4	8
8-15	7	24	3	5	27	1.4	0.2	6.9	19	19
15-25	138	130	11	139	129	0.9	0.0	27.0	16	15
25-40	61	79	10	60	78	1.3	0.2	15.0	9	11
40-95	30	10	5	18	25	1.6	0.4	4.2	11	29
95-135	42	19	6	23	22	1.3	0.4	5.7	12	11
135-175	50	33	7	16	82	1.4	0.2	6.3	11	11

**CEC, Cation Exchange Capacity; O.C., Organic Carbon; C/N, Carbon-Nitrogen ratio; EC, Electrical Conductivity; SAR, Sodium Adsorption Ratio; ESP, Exchangeable Sodium Percentage.*

forces, because changes in hydraulic conductivity were generally consistent with measurement of clay dispersion.

Soil classification

According to the climatic, morphological and physiochemical data, Akkad soil can be classified as sodic haplo cambids, fine, smectitic, hyperthermic; while Binna can be classified as sodic haplo cambids, fine, mixed, hyperthermic. It is clear that both soils are similar down to the subgroup level, but differ at the family level in their type of mineralogy. The dominant clay mineral is smectite in Akkad, while in Binna the minerals are mixed due to its position near the high Nubian sandstone. This is apparent in the particle size distribution where the percentage of sand is higher in Binna than in Akkad. The smectite clays coupled with high adsorbed and dissolved sodium affected the soil physical properties such as hydraulic conductivity, infiltration rate and structural stability.

Traditional farmer practices

The main traditional agricultural practices for reclaiming saline and/or sodic soil, adopted by the local farmers, are ploughing the land, dividing it into small plots (5¥4 m^2), adding farmyard manure (about 7.5 t/ha), levelling and applying flood irrigation at short intervals (3 to 4 days). They usually grow wheat and barely to a lesser extent during winter, whereas summer crops are not grown due to the scarcity of irrigation water and limitation in economic summer crops. Hence the leaching process is not complete because of the summer fallow. This situation might again promote the upward movement of the soil solution to concentrate and precipitate salts in the root zone. Moreover, some salt spots with a thin crust surface layer, bare without plants, were observed in the cultivated plots (fig 8). Rhoades (1990) stated that flooding irrigation is suitable for salinity control if the land is sufficiently levelled, although anaerobic soil conditions and crusting may occur.

The results of the chemical analysis

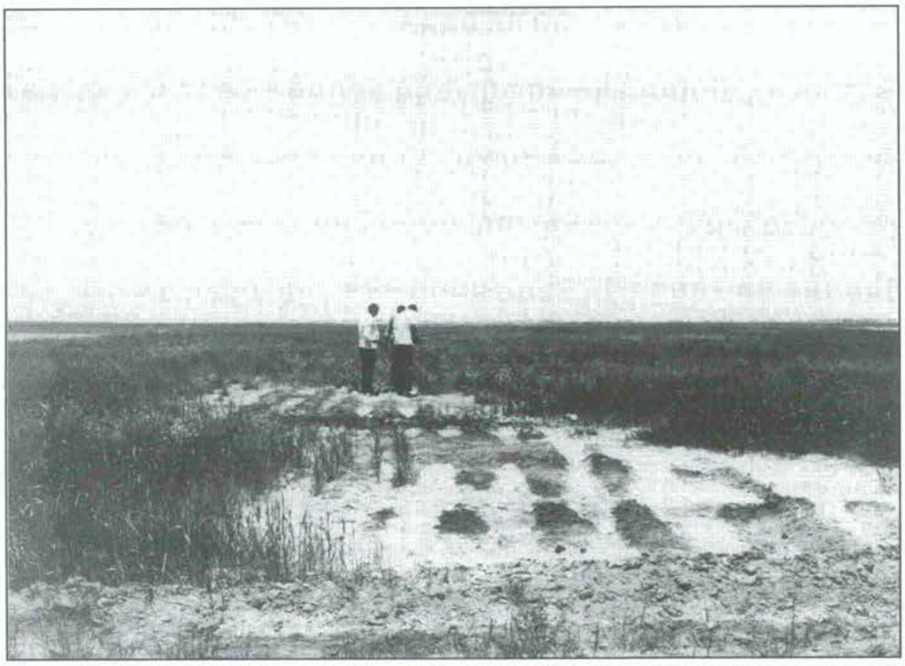

Figure 8. *Spots of salt accumulation in farmer fields not reclaimed (no addition of organic manure).*

Table 2. Particle size distribution for soil profiles of Akkad and Binna series.

Soil Depth (cm)	Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	H_2O (%)	Texture Class
Akkad Series						
0-5	7	32	21	40	60	Clay Loam/Clay
5-30	4	22	25	49	87	Clay
30-45	2	15	32	51	80	Clay
45-70	1	14	38	47	83	Clay
70-105	3	18	48	33	71	Clay Loam
105-155	0	13	38	49	75	Clay
Binna Series						
0-8	20	48	13	19	32	Sand Loam
8-15	6	30	37	27	53	Clay Loam
15-25	5	28	30	37	54	Clay Loam
25-40	6	28	26	40	36	Clay Loam/Clay
40-95	5	27	28	46	62	Clay
95-135	6	26	33	35	66	Clay Loam
135-175	8	26	23	41	62	Clay

of salinity and sodicity of the cultivated plots and the adjacent virgin lands are shown in table 3. The data revealed a significant decrease in the EC values, but the sodicity was decreased only in the upper 30 cm with no significant decrease in the lower horizons. These results indicated that the farmers' traditional reclamation was more effective in decreasing salinity in both series. The farmers' practice did not significantly reduce the sodicity in both series. However, the sodicity was more reduced in Binna than in the Akkad series. This was due to the fact that the Binna series has a lower clay content, moderately rapid drainage and more soluble Ca^{2+} than Akkad. Reclamation of saline soils is usually carried out by simple leaching with good quality water, while for the improvement of saline-sodic and sodic soils, replacement of exchangeable sodium with calcium is required (Rhoades, 1990; Stainberg, 1990). Therefore, in order to reduce effectively the sodicity of these soils, the application of gypsum together with the present farmers' practice is advocated. The favourable effect of exchangeable calcium and the adverse effect of exchangeable sodium on soil swelling and dispersion is well known (Keren, 1996).

The land evaluation in table 4 shows that both soils are currently unsuitable (N1), according to Van der Keive's classification (1976). The main limitations are very high salinity (S_4) and moderate (a_3) and slight (a_2) sodicity. The frequent irrigation and addition of farmyard manure improved the potential land suitability of both series. The salinity was decreased to less than 4 dS/m in Binna, i.e non-saline (S_1), and less than 8 dS/m in Akkad, that is slightly saline (S_2). Binna series is slightly sodic (a_2) with ESP up to 16, while Akkad series is moderately sodic with ESP up to 27 (a_3). It is clear that leaching and addition of farmyard manure have not effectively solved the problem of sodicity. There is a need to apply gypsum ($CaSO_4$) to replace Na^+ by Ca^{2+} to reverse the dispersion process to flocculation, which will improve the

Table 3. Effects of farmer practices on soil reclamation of Akkad and Binna series.

Soil Series Name	Texture Class	Soil Depth (cm)	EC (dS/m) Before Reclamation	EC (dS/m) After Reclamation	ESP Before Reclamation	ESP After Reclamation	Conventional Farmer Cultivation Practices
Akkad	Clay	0-30	32	3.6	35	7	Wheat for 2 seasons (winter) + FYM*
		30-60	24	7.8	31	27	Sorghum 1season
		60-90	7.7	5.2	25	20	(Summer) + FYM
Binna	Clay	0-30	6	1.4	22	14	Wheat for 2 seasons + FYM
	loam	30-60	23	3.4	23	12	
		60-90	5	4.9	15	16	

FYM, Farm yard manure.

Table 4. Land suitability classes and subclasses (Van der Kevie, 1976) for Akkad and Binna series before and after the farmer conventional reclamation.

Soil Series Name	Suitability Class		Suitability Subclass	
	Virgin	Cultivated	Virgin	Cultivated
Akkad	N1	S3	$N1a_3s_4$	$S3a_3s_2$
Binna	N1	S2	$N1a_2s_4$	$S2a_2s_1$

S2: moderately suitable; S3: marginally suitable; N1: currently unsuitable.

a: Sodicity. Degree of sodicity: 1, non-sodic; 2, slightly sodic; 3, moderately sodic; 4, strongly sodic.

s: Salinity. Degree of salinity: 1, non-saline; 2, slightly saline; 3, moderately saline; 4, strongly saline.

permeability to leach the Na^+. Gypsum alone or in combination with organic manure might be considered the most practical, effective and efficient amendment for reclamation of saline-sodic or sodic soils.

On the basis of the obtained results, the soils of the study area can be grouped in two categories:

1. Soils that can easily be reclaimed (Binna series);
2. Soils that are difficult to be reclaimed (Akkad series).

Both series have good water quality for irrigation either from the River Nile or deep- bore wells in the aquifer of the Nubian sandstone. Fortunately, the water-table is deep and cannot create conditions for secondary salinization. The gravelly sand substratum and the absence of restricting layer are favourable for reclamation of both soils. The Akkad series has a high amount of smectite clay, which shrinks and swells upon drying and wetting, while the Binna series has less clay per cent and mixed mineralogy. The high smectitic clay affected the soil drainage and the rate of internal drainage of Akkad. Reclamation of Akkad requires a certain flow of water through the profile, and appropriate hydraulic conductivity, as well as infiltration rate, must be achieved by tillage combined with application of correctives, especially gypsum.

Conclusions and recommendations

The results showed that high salinity and variable degrees of sodicity, depending on the past textural sedimentation processes and the present physiographic position, affect the soils of the Nile higher terraces. The physical properties of the soils indicated that the amounts of the smectitic clay content associated with appreciable amount of sodium are higher in the Akkad rather than in the Binna series. Thus, Akkad has adverse physical properties such as surface crusting, low infiltration rate and slow hydraulic conductivity. Before conventional reclamation, both soils were classified as currently unsuitable to produce economic yields and need to be reclaimed. The management practices of the farmers, to some extent, improved the Binna series and lowered its salinity and sodicity, while in Akkad these practices only decreased the salinity. Most of the key items for reclamation were found to be favourable, except the soil drainage, especially in Akkad. Reclamation of the salt-affected soils of the Nile higher terraces requires the improvement of structural stability and the internal drainage by replacing the sodium with calcium.

Therefore, to achieve successful reclamation of the salt-affected soils of the Nile higher terraces, the following recommendations must be taken in account:

1. Ripping the soil to a depth of at least 50 cm, followed by disc harrowing to improve the internal drainage;
2. Addition of gypsum, together with organic manure, its quantity, depending on soil analysis;

3. Avoiding summer fallow by cultivating salt-tolerant crops to prevent salt accumulation at the soil surface due to high evaporation;
4. Application of more irrigation than the crop water requirement in order to leach more salts;
5. Improvement of the current reclamation by conducting further multidisciplinary research.

Acknowledgement

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Carbon Sequestration: a Powerful Incentive for Combating Desertification

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Introduction

For many countries combating desertification, carbon sequestration to reduce greenhouse gases has tremendous potential as an incentive for soil conservation and forestry activities. In this article some of those possibilities and also some of the obstacles to their achievement are discussed. Examples from Iceland are used to illustrate the importance of strong links between the Climate and Desertification Conventions.

Desertification and carbon sequestration in Iceland

Desertification and other forms of soil erosion are rarely expressed as vividly as in Iceland. During eleven centuries of settlement, about 95 per cent of the original woodlands have been lost and about half of the vegetation cover. The loss of tree cover and overgrazing of the land have led to catastrophic soil erosion which has devastated the Icelandic ecosystems. Climatic variations have speeded up the process, increasing the vulnerability of natural resources to the pressures of land use.

More than 37 per cent of the country is now a barren desert, despite ample precipitation over most parts of it. Generally, the fertility of the remaining soils has been greatly reduced; poor land health and continued soil erosion are considered to be the most severe environmental problems in Iceland.

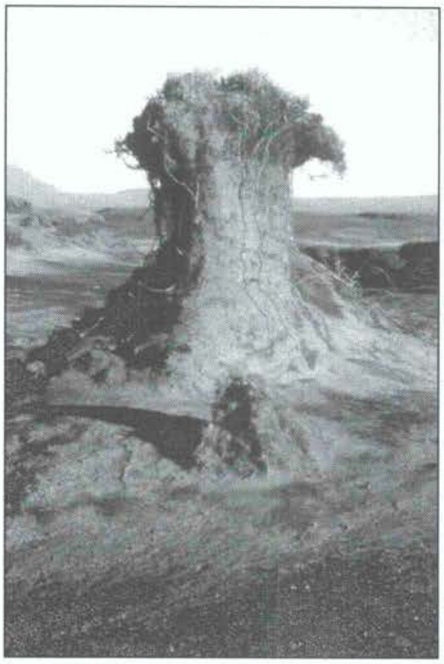

Photo 1. *A soil remnant — the result of erosion.*

One of the consequences of the extensive ecosystem disturbance in Iceland is that there is a high potential for carbon sequestration in both soil and biota. Such goals are increasingly shaping conservation projects, and the experience shows that restoring ecosystems and reducing atmospheric carbon can be combined with multiple benefits. Halting soil erosion is very important to prevent the release of stored carbon to the atmosphere. Thus, soil conservation certainly has a crucial role as one of the tools for stabilizing greenhouse gas concentrations and preventing climate change.

Measures to combat the desertification of Iceland began in 1907. Successful soil conservation work, and a great need for increased soil fertility, inspired the Icelandic Government in 1995 to include carbon sequestration as an important part of the National Climate Change Action Programme for the period 1990 to 2000. Projects aimed at reforestation of damaged land were greatly expanded, partly under the theme of 'reclamation forestry'. Many new projects have also been initiated for combating desertification and healing eroded land.

The role of carbon sequestration as a tool in meeting targets in greenhouse gas emissions has resulted in a 30 per cent increase in budgets for forestry and soil conservation in Iceland. The link between the goals of the Desertification and Climate Conventions has thus become one of the biggest financial incentives developed for soil conservation and forestry in recent years.

Greenhouse gases – a resource out of place

In the April/May issue of Conservation Voices the SWCS presents the view that carbon, as a dangerous greenhouse gas, is also a valuable resource. Carbon dioxide is one of the principal culprits named in the global warming debate. The same carbon molecule, when located in soil, becomes organic matter, the key to soil

Photo 2. *Reclamation of denuded land in Iceland.*

fertility and increased food production for the world's growing population.

Globally, there is great potential for increasing soil carbon through the restoration of degraded soil and other soil conservation practices. This potential varies greatly. However, the Icelandic experience illustrates the great carbon sequestration potential of some of the degraded lands of the world, both in soil and biota, providing for long-term storage of atmospheric carbon.

Carbon sinks

The Kyoto Protocol, which obligates developed countries to reduce their greenhouse gas emissions (Annex I), contains several important provisions on land use change and forestry. It was a significant step in bringing terrestrial carbon sinks into a legally binding framework.

The protocol determines how and which activities are counted as greenhouse gas sinks. However, the current limitations of terrestrial sinks to strictly defined cases of 'afforestation, reforestation and deforestation' seriously limits its effectiveness with regard to desertification issues. These limitations, if strictly defined, may exclude soil conservation as a carbon sink and be considered contradictory to the goals of the desertification and climate conventions. The same may apply to the convention on biological diversity.

Care has to be taken that forest definitions with regard to the climate convention are broad enough to meet the goals of the desertification convention. For countries affected by severe land degradation and desertification, it is especially important that forests as carbon sinks are not defined with a boreal bias (only tall trees). Small trees, bushes and open woodlands often characterize areas prone to desertification. Recognition of these characteristics is vital with regard to forest definitions in the Kyoto protocols. Otherwise, carbon sequestration as an incentive to using trees and shrubs for soil protection would be excluded in vast areas of the world, including Iceland. The danger of clearing in areas not meeting classical forest definitions would also be avoided.

Soil carbon sequestration in afforestation must be accounted for. A large proportion of the carbon pool is below ground, and is often a more permanent storage than the wood. Therefore, the total contribution of a forest to a national carbon budget is what matters.

The use of trees certainly is an important tool in the implementation of the Convention to Combat Desertification (CCD). However, it would be mutually supportive for the objectives of the climate and desertification conventions to add other actions related to combating desertification to the list of carbon sinks. This includes land reclamation and land use changes, such as protecting degraded areas from grazing.

The Kyoto Protocol allows parties to negotiate additional sink categories. Such work is under way, and the IPCC has been asked to produce a special report on land use, land use change and forestry emissions. In the light of accountability and the importance of the issue, Iceland has encouraged the inclusion of 'direct

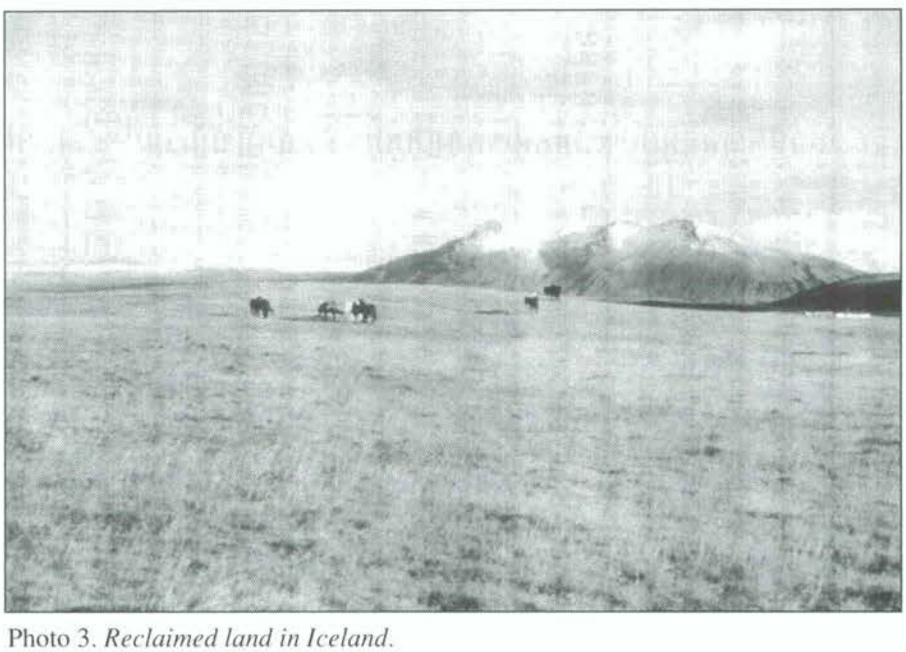

Photo 3. *Reclaimed land in Iceland.*

actions to increase carbon stocks in soils with low organic matter content'.

Big stakes

Approval of carbon sinks adapted to land degradation issues, such as increased soil carbon through reclamation, would be a great incentive for combating desertification. In some countries, such as Iceland, this would step up both government and industry funding for soil conservation projects. It would also encourage development of much needed alternatives for land use changes in degraded areas.

The Kyoto Protocol includes provisions for the establishment of the 'clean development mechanism'. Its basic premise is that projects undertaken in developing countries can be counted towards meeting greenhouse reduction targets of developed countries. Many vital issues must be resolved, but this may be regarded as a 'win-win' opportunity. The developed countries could invest in cost-effective actions that help them meet their legal commitments under the protocol. Funds for mitigating desertification would be encouraged, in a voluntary manner. Developed and developing countries could thus engage in a mutually beneficial co-operative effort to meet the climate change challenge. This opportunity should be used to the benefit of food security. The 'big winners' would be the countries most affected by desertification, especially the poorer countries. The key to this, however, is the acceptance of appropriate soil carbon sinks in the legally binding frameworks of the Kyoto Protocols.

Masters of Disaster in Cholistan Desert, Pakistan: Pattern of Nomadic Migration

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Introduction

The Cholistan desert was a fertile and well populated area when the Hakara river flowed through it around 4000 and 1000 BC. When the river and its tributaries changed course and dried up 600 years ago, the settlements began to disappear and the people of the area were forced, by an unbearably harsh environment, to migrate to more favourable places to lead their nomadic life. The old bed of the Hakara river still shows the remains of a series of decayed forts (Akbar et. al.., 1996; FAO, 1993).

Today, the semi-arid to arid Cholistan receives 100 to 250 mm rainfall per annum with sand dunes of variable heights, interspaced with interdunal compact, flat and saline plains *dahars*. Small sand dunes with extensive flats of alluvial/loamy nature (*dahars*) are found in the north-western part (Lesser Cholistan) and very high dunes in the south (Greater Cholistan) with none, or less flat, *dahars* (Arshad and Rao, 1995). In the absence of arable farming in the desert, a variety of human food of plant origin is obtained from adjoining areas. However, some edible parts of certain desert plants, including fruits, may be eaten to tide over food shortages, which are inadequate for sole dependence. Lack of perennial sources of potable water is another major factor that does not permit permanent settlement in the desert.

In the absence of permanent settlements inside the desert (except small irrigated parts) the Cholistani pastoralists lead a nomadic, migratory way of life. This migration is determined by the availability of potable rainwater and the amount of forage in the pasture. A body

Monthwise migratory patterns of nomad pastoralists in Cholistan Desert

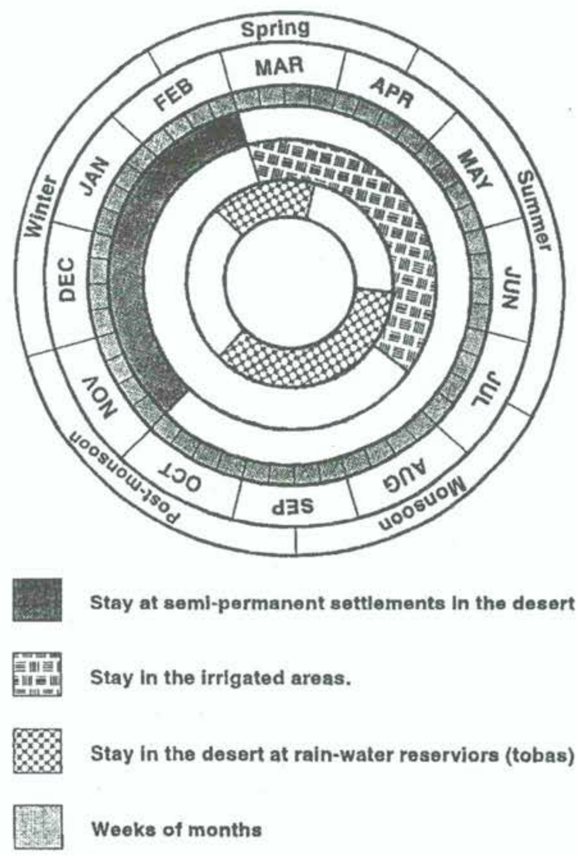

Photo 1. *A typical 'toba'. Water point for nomads and their livestock.*

of water, formed by the surface runoff rain water in the low lying depressions, locally called toba, is the pivot of life for humans, their animals and wildlife as the subsoil water is highly brackish and unfit for use. Temporary stays around water points (tobas) continue until all the surface water and its subsoil recharge, raised from the dug-out earthen wells by draught-animals (camels) is exhausted. As the wells dry up, graziers must move and search for new areas with an intact useable body of water. This migration continues until all the water-bodies in the area are exhausted or are dried up due to high summer temperatures. This is the harshest and most inhospitable period of summer; violently agonizing and a disappointing turning point, leading to the exodus of the pastoralists and their animals on a massive scale, leaving behind their temporary hutments (gopas). The nomads will settle temporarily on the outskirts of the desert, where there may be canal water and fodder available from approximately the end of March to mid-July (fig 1). These farmers do not 'own' water and grazing grounds of their own, so the nomads tide over this period there in spite of the resentment of local 'hosts'.

Water pools or tobas within the desert are generally owned by tribes or families. Some of them are periodically excavated to increase their water reserve capacity. Normally, other herders will not use them without the owners' prior permission, without which it is considered an offence, attracting some minor penalty. Water points, being vital hubs of activity, indirectly intensify desertification. The bigger the water body, the longer will the animals stay, leading to higher pressure on grazing, thus triggering over-exploitation of the pasture's bio resources causing increased desertification. Conversely, the longer the distance from the water point or semi-permanent settlements, the richer and thicker will be the vegetation cover. The absence or drying up of a water body may, in a way, be a blessing in disguise to the desert flora. Apart from some shade trees, (*Prosopis, Zizyphus, Tamarix* and *Acacia*) which are generally protected round the toba, most herbs, shrubs and trees are extensively eaten by domestic animals, which leave behind only dried, unpalatable and hard stubble. The soil, in spite of higher organic matter (FYM), is extensively trampled by the animals, gets loosened and pulverized so that the seedlings cannot withstand the onslaught and die. With the increasing intensity of grazing the seed production capability of the endemic species is jeopardized; this reduces the subsequent regeneration potential, which continuously degrades the range. Lack of sufficient rain, the long distance from, or absence of, a nearby water point, inaccessibility or difficult approach to the grazing ground indirectly helps the vegetation to recoup or rehabilitate; even a mild drought may help the floral increase.

Large herd size also prompts nomadic migrations as it will rapidly devour the vegetable resources and the drinkable water prompting a search for other sources of water or fodder. Permanent settlements around perennial water sources also experience excessive grazing of 'ice cream' species, leaving less desirable species like *Aerva, Calotropis, Cymbopogon*, etc. (Rao, et. al., 1989). A few recently built metalled roads

Photo 2. *Thirsty cows and camels around a lifted rainwater well.*

encouraged deeper grazing and harvesting of plant materials coupled with speedier transport for migration. High summer temperatures tell heavily on human and livestock lives, but unusually heavy rain will not stop the nomads' immigration towards the desert interior.

Seasonal responses and grazeable periods

Ephemerals, annual grasses and short-leaved forbs appear only after rain showers, be they monsoon or winter falls. Active and abundant plant growth is seen in the moist period lasting 4 to 10 weeks of the monsoon (July and August), and is reasonably good in the spring after winter rains. Among the perennial grasses *Lasiurus scindicus, Cyperus conglomeratus, Cenchrus ciliaris, Panicum turgidum, Panicum antidotale, Sporobolus iocladus, Aeluropus lagopoides* and *Ochthochloa compressa* appear to be the hardiest as they tolerate prolonged drought and heavy grazing pressures (Rao and Arshad, 1991). Under severe drought, aerial tillers of these grasses start drying up from the outer to the innermost; this is the stage where grazing pressure will be warded off, however, if sub-soil moisture dries up hundreds of the tillers of the stool will die, and the rate of desertification escalates.

Calligoituni polygonoides, Haloxylon salicornicum, Haloxyon recurvum, Salsola baryosma, Leptadenia pyrotechnica, Aerva persica and *Capparis decidua* generally are site specific, most resistant to salt and drought and stay evergreen for long, whereas *Suaeda fruticosa* behaves as a semi-evergreen plant besides being highly salt and drought tolerant.

Pre-monsoon summer

This refers to the period starting from March/April to mid-July prior to the onset of the monsoon rains. It is the hottest and the driest period of this desert intensified by strong, persistent, hot and dry winds. Day temperature may rise above 50°C. The vegetation is at its minimal during this period and there is virtually no forage or water for the animals. The pastoralists migrate with their livestock to their allotted pieces of irrigated lands or to other irrigated areas. Few tested and tried head of very hardy Cholistani breeds of animals (cattle, goats and sheep) subsist or forage on hard and salty shrubs and trees, namely *Calotropis procera, Cymbopogon jwarancusa* and *Capparis decidua*, even with only a little highly saline water from dug-out wells left in the area. One or two herdsmen left behind will try to manage short distance grazing from their semi-permanent settlements, particularly at night. The livestock remain underfed, lose vitality while weight and milk production substantially decreases. Any miscalculation or false hopes about the rain may lead to animal mortality on a large scale, virtually littering the area with the corpses of the animals which suffer huge losses; those in the deeper desert suffer even worse. The scarce wildlife also suffers.

During the month of June, if unusual rains set in the pastoral nomads immediately rush their livestock to Lesser Cholistan caring little about the harsh environmental conditions. At that time cattle, sheep and goats graze upon the rapidly sprouting *Cymbopogon jwaranscusa, Capparis decidua* and *Ochthochloa compressa* while the camels feed on *Prosopis cineraria, Calligonum polygonoides, Haloxylon salicornicum, Calotropis procera and Salsola baryosma*. An untimely and unexpected wet spell may prove an awful animal death trap if monsoon showers, expected a month later, fail or are delayed beyond August. Hoping against false hopes, it leaves very little time to evacuate, resulting in the death of animals on large scale.

During daytime when tempera-tures soar to more than 50°C or so the cattle, sheep and goats seek relief under the shade of *Prosopis citteraria, Capparis decidua* and *Calotropis gigantea*, if available, otherwise they fight off the agony by dipping themselves in muddy water. Similarly, the camels lie down in the mud to save them from the scorching heat of the day.

Monsoon

The monsoon is the rainy period which starts from mid-July, reaches its climax in August and gradually subsides in early September. The monsoon winds followed by showers lower the temperature rendering it more tolerable, but this state is short lived and it may turn hot quickly. In general, the humidity percentage remains low thus the evaporation/transpiration remains high, nullifying the effectiveness of rainfall. Part of the rainwater that percolates into the sandy soil is enough to activate seed germination. After germination perennial grasses/ephemerals, etc. mature rapidly and the desert turns green and blooms profusely;

Photo 3. *The fate of animals when exodus is delayed in severe drought.*

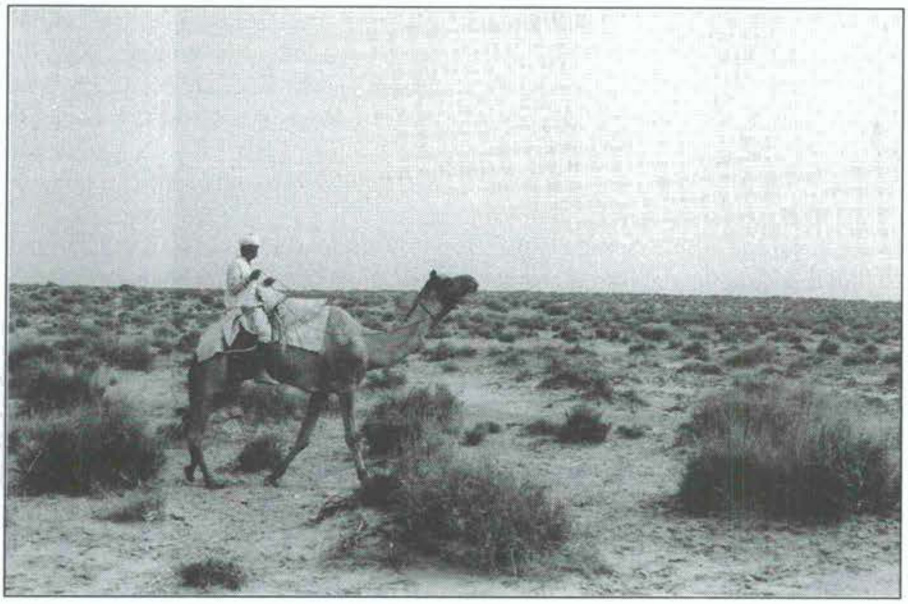

Photo 4. *A happy camel rider in blooming desert.*

vegetation cover, species composition, biomass and palatability is at its best. Abundant forage is available for all kinds of livestock, which gain weight, enhance their productivity and prepare themselves for the vagaries of the approaching inclement and dry autumn.

In the case of normal or sufficient rain during the summer the pastoralists, prefer to stay with their herds in Greater Cholistan in their temporary abodes *(gopas)* and *tobas*. After about two months' stay, they move for a month or so towards their tobas in Lesser Cholistan, an ideal period of two to three months with ample pasturage. During this period the livestock gain weight and milk production increases, wildlife partially returns to the jungle and the desert no longer appears to be a desert as the vegetation cover will increase up to 40 per cent as compared with a desolated state with merely 5 per cent cover.

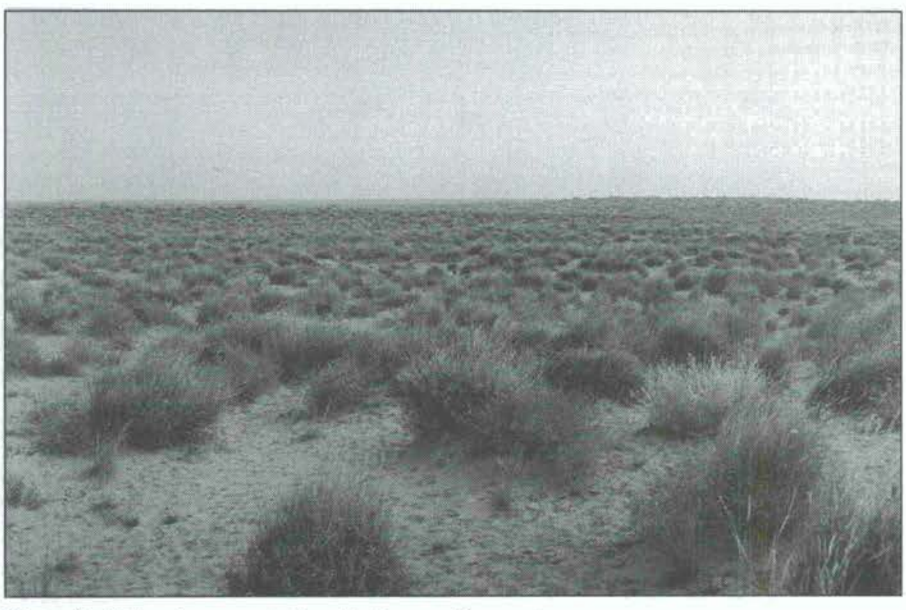

Photo 5. *Yellowing vegetation during cooling autumn.*

Post-monsoon (autumn)

The post-monsoon season refers to autumn, lasting from October to November (six to eight weeks). During this period the temperature decreases considerably but aridity will prevail due to low humidity. The flowering and seeding flush is completed in almost all the annuals/ephemerals and perennials. *Calligonumi polygonoides* and *Dipterygiumi glaucum* dry out partially but forbs dry out completely. There is, however, enough forage available in the eastern zone of Cholistan. By the end of the autumn season, water in the tobas and *kunds* runs out and the pastoralists with their livestock and households start moving towards the semi-permanent settlements, *abadies*, such as Bijnot Fort, Nawankot Fort, Islamgarh Fort, Rasoolsar, Chah Bhai Khan Wala, Fort Din Garh and Fort Islam Garh, where water from numerous dug-wells will last for another couple of months and the pastoralists will stay there till the end of winter (January/February).

Winter

The winter season refers to the period from December to January characterized by low temperatures, reduced by occasional northern cold winds, with a few frosty nights (less than 0°C), low and sporadic rains and low evapotranspiration, otherwise the winters are mild, making the perennial plants dormant. The plants that remain green or partially green are *Calligonum polygonoides, Haloxylon salicornium, Crotalaria burhia, Leptadenia pyrotechnica, Tamarix aphylla.* Cattle, goats and sheep survive on dry stubbles of *Lasiurus scindicus,. Cymbopogont jwarancusa, Ochthochloa compressa, Stipagrostis pluniosa*, dry forbs, dry fallen leaves or branches of annuals and non-palatable plants such as *Calotropis procera and Capparis decidua. Prosopis cineraria* and *Acacia nilotica* provide additional forage for camels. This is another stressful period where animals remain underfed and malnourished with low production. When the conserved or recharged rainwater in

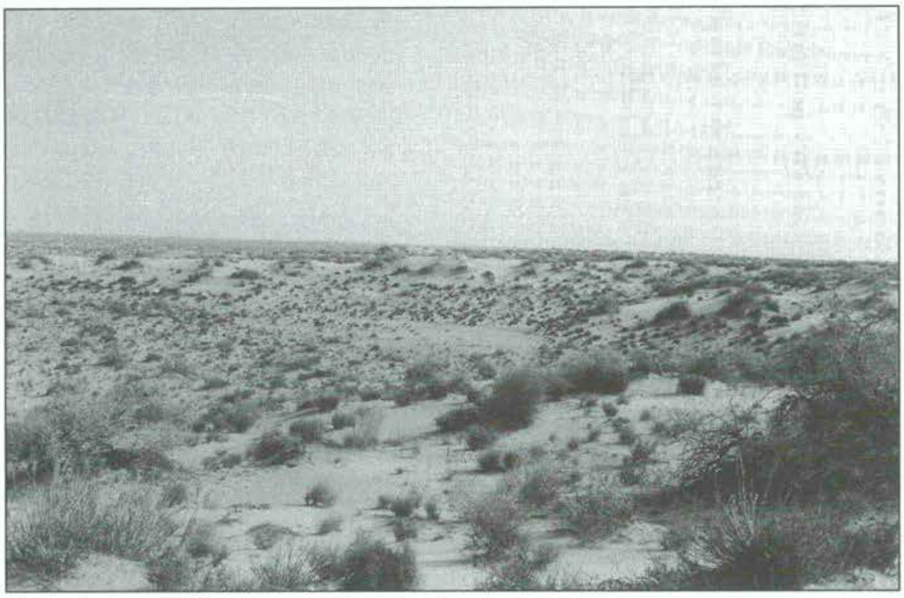

Photo 6. *A partially overgrazed wintry desert.*

the wells is exhausted the annuals have to resort to highly saline water causing debility and/or death if the use of this water is prolonged with virtually very little to eat in the pasture. To avoid this critical stage, very weak or a few 'precious' animals are administered grains and/or flour as a concentrate from their own food so that they are able to move to the grazing grounds.

Spring

The spring season refers to the period starting from February to March where the temperature is very pleasant. If heavy winter rains are received, the vegetation sprouts with enough drinking water to make herds and herdsmen happy. Light showers do not generate runoff, thus tobas remain dry and well water is not replenished. Late rains in March/April may help the animals to stay longer in the desert, although any delay in the exodus can have disastrous consequences, as the rapidly rising temperature may make the sustainability worse in a very short period of time.

When the temperature shoots up and there is no water the pastoralists with their livestock migrate towards the irrigated areas once again and will stay there till the monsoon bursts. The herds roam and graze whatever has been left behind in wastelands by the local herds. This is not a happy state as the local farmers resent the arrival of competing herds. In the case of serious shortages some quantity of fodder is purchased, however the animals generally remain underfed, lose weight and their milk production decreases.

In the desert a water storage pond *(toba)* is the hub of life. It is generally owned by a specific clan who first established it. Around this water point 10 to 12 families temporarily camp in their hutments or *gopas* along with their livestock. Most *tobas* have few shade and fruit-bearing trees. Common shady trees are *Prosopis cineraria, Acacia nilotica and Tamarix aphylla* while the only fruit tree is *Zizyphus spina christi*. Two to three metre-high mud embankments channel the rainwater run-off from the *dahar* (water harvesting zone) to the low lying pond. A trench with a low parapet is made at the edge of the pond, to obstruct the approaching thirsty animals. Water from the *toba* is allowed to flow into the outer trough from which the animals drink without fouling the water because the inhabitants also share the same water. With the lowering of the water surface a new trench and parapet is prepared until all the water from the *toba* is finished.

Useful information about the status of water in the tobas, wells and pasture condition is exchanged willingly by the nomads and plans are accordingly made for their move. Normally permission is sought before migrating to another owner's water source *(toba)*. The owner will generally enquire about the number of animals, kind of animals and duration of stay, etc. before agreeing. If permission is given, no payment is charged except sharing the cost and labour of digging, trenching and making parapets in the following season. Generally the herds are disciplined before they are brought to the drinking point; for example, at a shrill whistle, a flock of hundreds of sheep and goats will stop at their places and wait for their turn; at another signal, the animals will move away from the water point.

Big animals freely graze in the desert

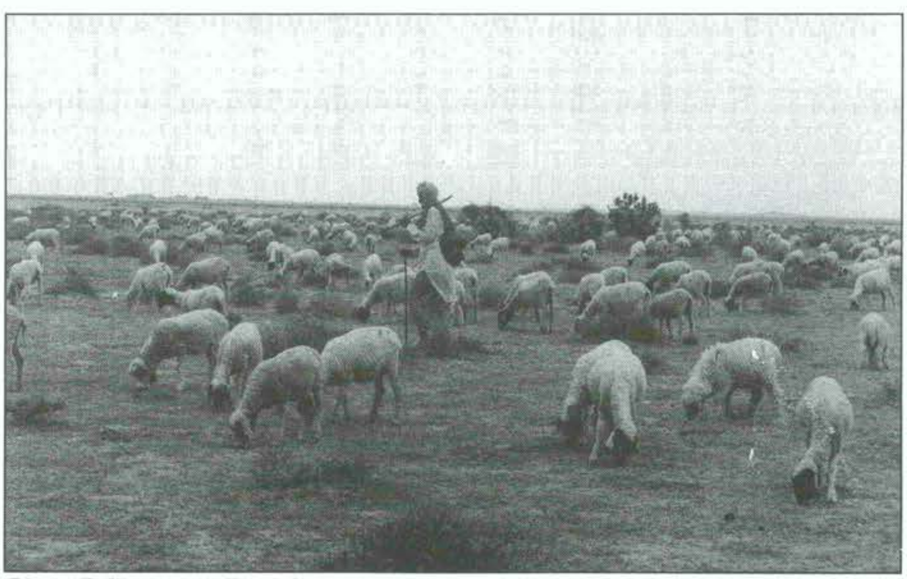

Photo 7. *Young seedlings being grazed; the worried shepherd with his water pot on his back.*

unattended except by the sheep and goats. Owners recognize their animals by the distinctive sound of bells or by the *braderi* brands or tattoo marks on the hind legs or ears of cows and camels. Each tribe and clan has its own distinctive mark. Some markings are given below.

Tribe Name Symbol	Tribe Name Symbol
1. Larr	6. Rajar
2. Sheikh	7. Kallar
3. Mehr Bhai Khan	8. Tanwari
4. Mehr Matoia	9. Buharr
5. Mehr Bend	

Socioeconomic aspects of land use

Livestock grazing is the most extensive land use in the Cholistan desert. The economy of the desert dwellers *(Rohilas)* primarily depends upon herding and grazing. Camels, cattle, goats and sheep are bred for sale and milked to prepare butterfat (ghee). Sheep, goats and camels are shorn for wool, their hides and skins are also marketed. Another class of dwellers (Gaderri) trade in the hides and skins of wild and domestic animals. Sajji (carbonate soda) is obtained by burning *Haloxylon recurvuni* and *Suaeda ftuticosa* and sold. These two plants grow abundantly in the saline *dahars* of the area, and their over burn has resulted in the degradation of the vegetation cover. In many parts of the desert sand dunes are being destabilized, aggravating wind erosion and the rate of desertification. Deterioration in the vegetation resources is also partially due to increasing demand for fuel, etc. largely originating from settled areas. Shrubs like *Haloxylon salicorniticumi* and *Calligonum polygonoides* are extensively cut or uprooted and transported using bicycles, donkeys, wagons, tractors, etc. Vehicular transport plays havoc in rapidly denuding the jungle, more severe damage is seen towards the newly cultivated and/or irrigated areas of the desert (Akbar and Arshad, 1998).

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Wind Erosion in North Kordufan State, Sudan

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Introduction

The international community has recognized that desertification is a major ecological problem with consequent dramatic socio-economic impacts (UNCED, 1992). The internationally negotiated and widely accepted definition of desertfication is 'land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors including climatic variations and human activities'. Main land degradation processes include degradation of plant cover, wind and water erosion, salinization, alkalization and soil compaction .

In Sudan, arid and semi-arid land (ASALs) cover an area of 1.7 million km^2 representing about 71per cent of the country's total area. Wind erosion is the major factor in the process of desertification in ASALs. Human activities that compound the degradation of plant cover, such as overgrazing, deforestation, over-cultivation (particularly in marginal lands), bush and casual fires promote wind erosion and compound desertification. The destructive effects of wind erosion include the removal of the top fertile soil layer, loss of soil productivity, the blowing away of seeds, seedlings and even crops, and the burial of agricultural lands and buildings.

Recently Sudan was divided into twenty-six states, sixteen of which lie within ASALs and which are, therefore, affected in varying degrees by desertification. So, desertification constitutes a major threat to Sudan's agricultural development. There is little basic quantitative data on wind erosion in Sudan. Thus there is a need to generate such data to enable relevant programmes for combating desertification to be designed. The techniques employed may prove valuable for monitoring and evaluation of such intervention measures.

The present experimental work was conducted in North Kordufan state because it is one of the most seriously affected states. The research was undertaken to achieve the following specific objectives:

1. Estimation of wind erosion as affected by site location and land surface;
2. Testing the use of vertical sand traps for estimating the intensity of wind erosion in Sudan;
3. Investigating the spatial and temporal variation of the intensity of wind erosion;
4. Prediction of potential intensity of wind erosion using an empirical functional model.

General setting of the state

The state lies between latitude 12° 30 15' north and longitude 27° 32' east. The sites selected for the study were around El-Obeid town, latitude 13° 10' north, longitude 30° 14' east, and at an altitude of 570 metres above sea level.

A tropical continental climate prevails, with most rain falling between June and September. The annual rainfall is variable, increasing from 350 mm in the north to 450 mm in the south. The mean daily temperatures for the period 1960 to 1990 ranged from 29.9°C to 39.4°C (max) to 13.5°C to 24.6°C (min). The main geomorphological features consist of sand sheets and low dune complexes in the north, longitudinal dunes along the prevailing wind direction in the east and a clay pediplain in the south. Two soil groups are dominant: Qoz sands (Psamments) in the northern and eastern parts and compacted 'Gardud' soils (Palustalfs) in the south. The sand sheets and dunes are mainly fixed with semi-desert scurp in the north and by low woodland savannah *(Acacia senegal, A. albida)* in the south. The soils have low fertility and are cultivated without the use of fertilizers. The main crops are millet, sorghum, water melons and groundnuts. Furthermore, they are subjected to man-induced degradation by over-cultivation, overgrazing and deforestration. Under these prevalent conditions wind erosion is overriding in the process of desertification. Encroachment of sand dunes on agricultural lands is evident on many locations (photos 1 and 2).

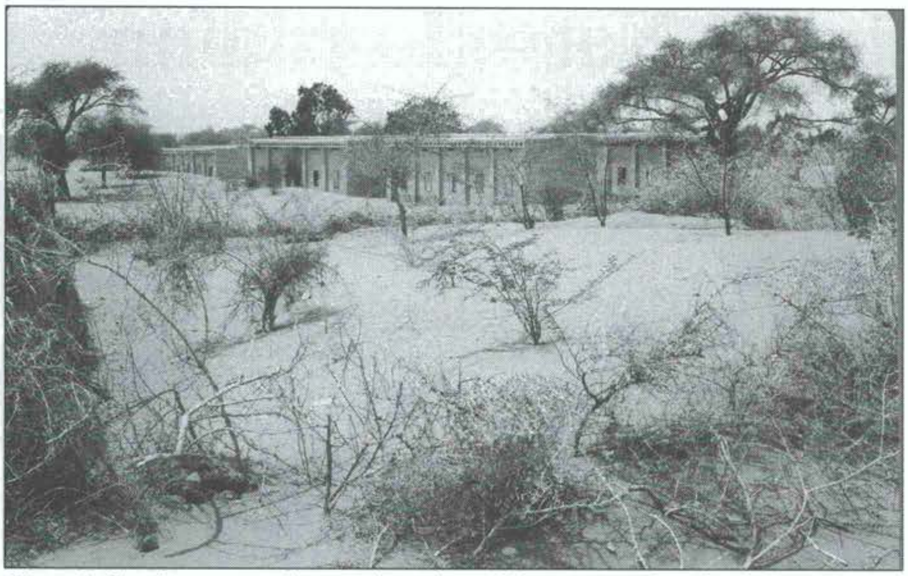

Photo 1. *Sand movement from activated sand dunes around a school. Um Eshera, North Kordufan, 1997.*

Site, materials and methods

The following sites around El-Obeid town were selected for the study:

1. The Western Sudan Agricultural Research Field (WSARP), 2 km north of El-Obeid. The soil is a sand sheet (Qoz). Two fields were used for the study, one bare and the other fallow.
2. Dammokia, an *Acacia senegal* forest on a sand dune, 30 km east of El - Obeid. Three field surfaces were used: a bare fallow and a burnt grass surface.
3. Banno, the soil is hard compacted dense soil 'Gardud', 20 km. south of El -Obeid .

Two fallow fields were used, one protected by fencing and the other unfenced. Two methods were used for determining the intensity of wind erosion: measurement by sand traps and predicted by an empirical model.

Field measurement by vertical sand traps

Vertical sand traps were constructed as described by Leatherman , 1978. Each trap consisted of two concentric PVC tubes open at one end and closed at the other. At the open end of the outside tube (90 cm long and 10 cm inside diameter), two rectangular slits (30 cm x 2.5 cm) were cut opposite to each other. One slit is aligned towards the prevalent wind direction to serve as a collection orifice. The opposite slit is covered with a fine screen that checks the movement of sand, while permitting minimum wind flow. The inside tube (60 cm long and 9.5 cm inside diameter) fits snugly inside the outside tube and serves as a sand collector.

In the field, the outside tube is inserted in the soil to a depth of 60 cm, so that the base of the slits coincide with the soil surface. The short tube is fitted with two wires to help in lowering it inside the long tube. A piece of cotton wool is used to close the narrow space between the two tubes.

In each field, vertical sand traps were installed at 0, 30, 60 and 90 metres from the windward edge. Three replicate measurements were made at each location. The mass of sand particles collected in the inside tubes were determined fortnightly and the intensity of wind erosion was calculated as mass per unit area of the slit per unit time (tonne/ha/ day).

Field measurement by horizontal traps

Cylindrical oil cans (I d = 17 cm) were used as horizontal traps. They were buried in the soil leaving the open end level with the soil surface. Three replicate cans were placed at each location. Fortnightly, the cans were removed, the collected sand was weighed and the intensity of wind erosion was measured. These horizontal trap measurements were made only in the WSARP site.

Prediction of potential wind erosion

The annual potential soil loss (E, ton/ acre/annum) was estimated by the

Photo 2. *Due to the action of wind erosion on a bare dune, a tree's roots are exposed; finally it fell. Um Eshera, North Kordufan, 1997.*

following empirical functional relationship (Woodruff and Siddways, 1964):

E = f ', *(I, K',C',L',V',)*
Where: f refers to function of
I' = soil erodibility index
K' = soil ridge roughness factor
C' = wind erosion climatic factor
L' = prevailing wind direction
V' = vegetative cover

The five-steps procedure outlined by the authors and the tables and charts presented in their reference were used for estimating E, and a factor was used to convert the units to the metric system.

Results and discussion

Predicted Potential Wind Erosion

Table 1 presents potential wind erosion (PWE) data for various studied field surfaces in the three experimental sites located around El-Obeid town in Sheikan province.

It is evident that three parameters, namely Is, K, and C are independent of the site. All studied surfaces were level and thus: Is was considered equal to 1, and since ridging was not practised in the area K is also considered equal to 1. The erosion climatic factor C was calculated from the data from the El- Obeid meteorological station, since the three sites lie within the same climatic zone. Thus the parameter that varied among field surfaces and caused variation in PWE values were soil erodibility (I) , field length along the prevailing wind erosion direction (L), and the equivalent quantity of vegetative cover (V).

In the WSARP site PWE value for the bare field was approximately 54 times that for the fallow field, despite the fact that soil erodibility for the latter field is 18 per cent higher than that of the former. It is evidence of the overriding determinant of wind erosion.

In the Dammokia site the three field surfaces yielded similar soil erodibility indices, but differed in L and V values. The bare field gave a PWE value about 76 and 1.4 times that of the fallow and burnt grass surfaces. Here again, the fallow field with the highest V index gave the lowest PWE values, but to a very limited extent. The soils of the Banno site are well aggregated and thus gave the lowest I values. Fencing helped in protecting the vegetative cover and caused significant reduction in PWE. However, the reduction in PWE was not proportional to the increase in V index. Fencing is an effective practical measure for protecting the plant from livestock. It is adopted in the rotational grazing system (photos 3 & 4).

Measured Intensities of Wind Erosion

Table 2 presents intensities of wind erosion (IWE) data on a bare field in WSARP Both spatial and temporal variations are highly significant (P= 0.0001).

The spatial distribution pattern of IWE data depicts a maximum at 60 m distance for the eight studied periods. The grand mean values showed the same pattern. This finding is in agreement with previous findings of Chepil (1940) who attributed this increase to the steady accumulation of erodible material towards the leeward side of the field. The wind picks up an increasing load of sand till this load exceeds its energy to pick up more, but it deposits a portion of its load.

Table 1. The potential wind erosion of field surfaces around El-Obeid estimated by wind erosion equation

Site and field surface	Soil and knoll erodibility: Soil erodibility tonne/ha annum (I)	Soil and knoll erodibility: Knoll erodibility (Is)	Soil and knoll erodibility: Soil and knoll erodibility IxIs=I'	Soil ridge roughness factor K	Wind erosion climate factor C%	Field length along prevailing wind erosion direction (L, = Df-Db(m)	Vegetation cover equivalent (V) Kg/ha	Potential wind erosion ton/ha/ annum
1- WSARP								
(a) Bare field surface	242.06	1.0	242.06	1.0	38.5	701.5	560.0	66.69
(b) fallow field surface	286.52	1.0	286.52	1.0	38.5	707.6	1344.0	1.24
2- Dammokia								
(a) Bare field surface	340.86	1.0	340.86	1.0	38.5	163.48	560.0	93.86
(b) Fallow field surface	340.86	1.0	340.86	1.0	38.5	305.0	31360.0	1.24
(c) Burnt grass surface	340.86	1.0	340.86	1.0	38.5	206.18	2800.0	69.16
3- Banno								
(a) Fenced fallow field	39.52	1.0	39.52	1.0	38.5	566.08	31360.0	1.24
(b) unfenced fallow field	24.70	1.0	24.70	1.0	38.5	566.08	1344.0	1.85

Photo 3. *Fencing of land promotes grass growth and soil protection against wind erosion. Banno, south of El Obeid, North Kordufan, May 1997.*

Photo 4. *Unfenced land with destroyed grass cover and hence low soil protection against wind erosion. Banno, south of El Obeid, North Kordufan, May 1997.*

Deposits of sand on the leeward side smooth out the exposed surface, and promote wind erosion thereafter. Temporal variation did not reflect a specific trend. At each distance IWE data showed marked temporal variation and, unlike spatial variation, no peak is evident. The trend for temporal variation may be a reflection of the temporal variability of wind speed.

In the fallow field of WSARP, both spatial and temporal variations of IWE data are significant at 1 and 0.4 per cent level respectively (table 3). The grand mean IWE values increased significantly with distance, reaching its highest value at 90 m. Unlike the data of the bare field no maximum is shown at 60 m distance. The IWE values obtained at 30 and 60 m distances are significantly different. It seems that the sand load in the wind is not high enough to exhibit a peak within a distance of 90 m. In general, the fallow field gave IWE values lower than the bare field. The IWE values at 30, 60 and 90 m in the former are 50, 18 and 4.9 per cent of those in the latter field respectively. It is evident that, unlike the bare field, no sand is progressively accumulated with distance from wind edge. Here again, the temporal variation did not depict a specific pattern.

Table 4 presents IWE data along a bare surface field in Dammokia site. Both spatial and temporal variations are significant at the 5 per cent level. The highest IWE values, obtained consistently at 30 m distance for all periods may be attributed to the presence of a small sand dune on the windward side facing the first trap.

Table 2. Intensity of wind erosion (Ton/ha/day) measure along bare field surface at WSARP by vertical sand traps, spaced at different distances from windward edge and at different periods (January to May, 1997)

Distance	Periods							
(M)	13-28/1	28/1-13/2	13/2-27/2	27/2-13/3	13/3-27/3	27/3-13/4	13-27/4	27/4-15/5	Mean
0	0.35	0.75	0.83	0.37	0.51	0.33	0.06	0.31	0.44 c
30	1.21	1.54	1.09	0.51	0.70	0.54	0.29	5.67	1.46 c
60	19.31	19.97	17.82	3.52	8.44	4.85	1.63	17.15	10.25 a
90	8.78	12.6	15.34	1.16	8.11	2.39	1.21	6.03	7.47 b
Mean	7.14 b	6.48 b	9.77 a	1.39 d	4.02 c	2.03 dc	0.80 d	7.32 b	-

Table 3. Intensity of wind erosion measured along a fallow in WSARP by vertical sand traps (ton/h/day), spaced at different distances from windward edge and at different periods at the second season (January to May 1997).

Distance	Periods								
(M)	13-28/1	28/1-13/2	13/2-27/2	27/2-13/3	13/3-27/3	27/3-13/4	13-27/4	27/4-15/5	Mean
0	-	-	-	-	-	-	-	-	-
30	0.024	0.400	0.219	0.130	0.270	0.090	0.070	0.580	0.222 b
60	0.350	0.002	0.402	0.270	0.340	0.220	0.100	0.420	0.264 b
90	0.480	0.740	0.830	0.370	0.510	0.330	0.060	0.130	0.496 a
Mean	0.258 bcd	0.491 a	0.482 a	0.257 bcd	0.374 abc	0.216 cd	0.074 d	0.439 ab	-

Table 4. Intensity of wind erosion measured along a bare surface in Dammokia site by vertical sand traps (ton/h/day), located at different spaces from windward edge and at different periods in the second season (February to May 1997).

Distance	Periods						
(M) bns	1/2-15/2	15/2-28/2	28/2-17/3	28/3-14/4	28/3-14/4	14/4-26/5	Mean
30	7.24	10.07	0.78	14.87	7.56	9.79	8.36 a
60	0.47	4.67	0.08	1.40	1.00	6.77	2.40 b
90	1.28	4.00	0.10	3.07	1.55	5.35	2.56 b
Mean	2.997 ab	6.24 a	0.272 b	6.45 a	3.37 ab	7.30 a	

Table 5. Intensity of wind erosion measured (ton/h/day), along a bare field surface at WSARP by horizontal traps, spaced at different distances from windward edge and at different periods in the second season (January to May 1997).

Distance	Periods								
(M)	13-28/1	28/1-13/2	13/2-27/2	27/2-13/3	13/3-27/3	27/3-13/4	13-27/4	27/4-15/5	Mean
0	5.36	7.19	9.43	1.07	6.72	3.57	2.10	27.63	7.89 c
30	6.40	7.81	5.61	3.40	4.42	7.80	3.39	58.65	11.58 c
60	101.62	40.33	78.19	22.2	41.23	34.24	7.47	108.0	54.125
90	104.56	46.39	96.55	12.53	38.62	35.38	27.49	138.22	61.97 a
Mean	53.795b	24.93c	47.439b	9.80d	22.75c	20.25c	10.11d	82.04 a	-

The IWE data obtained in the fallow field surface at the site were much lower than those in the bare field. Both spatial and temporal variations are not significant.

Table 5 shows the IWE values obtained by the horizontal traps for the bare field surface in WSARP site. Both spatial and temporal variations are significant at the 0.01 per cent level. For all periods, except the 4th and 5th periods, IWE values increased with distance reaching the highest value at 90 m distance. Interaction is significant indicating that variation of IWE values is dependent on the time of measurement. Horizontal traps on this bare field yielded much higher IWE values than vertical traps. Considering the grand mean IWE values, and expressing the values obtained by the horizontal traps as a percentage of those obtained by the vertical traps, we get 1793.2, 793.2, 528.0 and 829.6 per cent for the traps at 0, 30, 60 and 90 m distances respectively. Although both types of traps collect sand particles transported by saltation, sand creep and suspension, the horizontal traps yielded much higher IWE values than the vertical traps because the former collected sand particles transported from all directions, whereas the latter received particles brought along the prevalent wind direction only. Spatial and temporal variations of IWE values in the WSARP fallow field were highly significant. In most periods IWE increased with distance reaching its highest value at 90 m distance (table 5). The interaction was also highly significant. Expressing grand mean IWE data obtained by horizontal traps as a percentage of that obtained by vertical traps, we get 11.3, 10.5 and 15.8 per cent at 30, 60 and 90 m distance respectively. It is evident that the vegetation in the fallow field inhibited the difference of IWE values obtained by the two types of traps.

There is need for more research to identify a standard procedure for measuring IWE under varying conditions.

Comparison between measured IWE and predicted PWE values indicates that the model greatly underestimates wind erosion. This is due to the fact that the model is empirical and hence it is site specific. The tables, nomographs and curves were made for Garden City in Kansas and need some modification if they are intended to be used outside the set of conditions prevalent in that particular location.

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Aeolian Sediment Movements in Lower Alluvial Plain, Iraq

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Introduction

A detailed investigation was carried out within the 17th July Irrigation Project and an area surrounding the Saddam River, covering an estimated 15,000 hectares of agricultural lands covered with sand dunes. The investigation included desertification features, potential and acual soil loss and sediment movement. The result of the investigation showed severe desertification processes in the area. Using a general wind erosion equation and the FAO climatic factor, the potential soil loss was estimated to be between 5 T/ha/year up to 105.4 T/ha/year in original soil, and 138.8 T/ha/year in sand sheets. The measured actual soil loss and sediment movement varied with the prevailing wind direction. The quantity of collected sediment reached 105.6, 89.0 and 71.6 T/ha/year using the trench method, whereas these quantities reached 106.7, 95.3 and 78.0 T/ha/year using sand traps. The highest soil material loss was from the north-west wind direction followed by the west and north winds respectively. The values of the potential and actual sediment movements are comparable and closely related. The Fryrear model applied to the study area gave fairly reasonable estimations for the erodible soil fractions. It is recommended that sand traps plus simple mathematical models, adjusted to the soil and climate of the region, should be used for sediment movement and characterization on regional bases.

Poor soil/water management and severe climatological factors have changed extensive agricultural lands in Iraq's alluvial plains into the present bare, waterlogged soils covered with aeolian sand sheets and pseudo sand dunes. The formulation of appropriate measures for soil/water management, which may include reclamation of saline, waterlogged soils, sand dune stabilization and re-vegetation of bare lands, is required. The aims of this research are to disclose the desertification process in a region surrounding the Saddam River (Euphrates-Tigris drainage outfall) to measure both potential and actual soil erosion and the rate of sediment movement. The research area is located within the 17[th] July Irrigation Project, between the Euphrates-Tigris drainage outfall and the newly-dug Saddam River that covers an estimated 15,000 ha of agricultural lands, partially covered with sand dunes (figure 1). Data on the environmental, physical, chemical and mineralogical properties of the soil and sand dunes were adequately reported by various workers (2,6, 7, 10, 11).

Materials and methods

1. Surface soil samples from different locations in the study area were dried

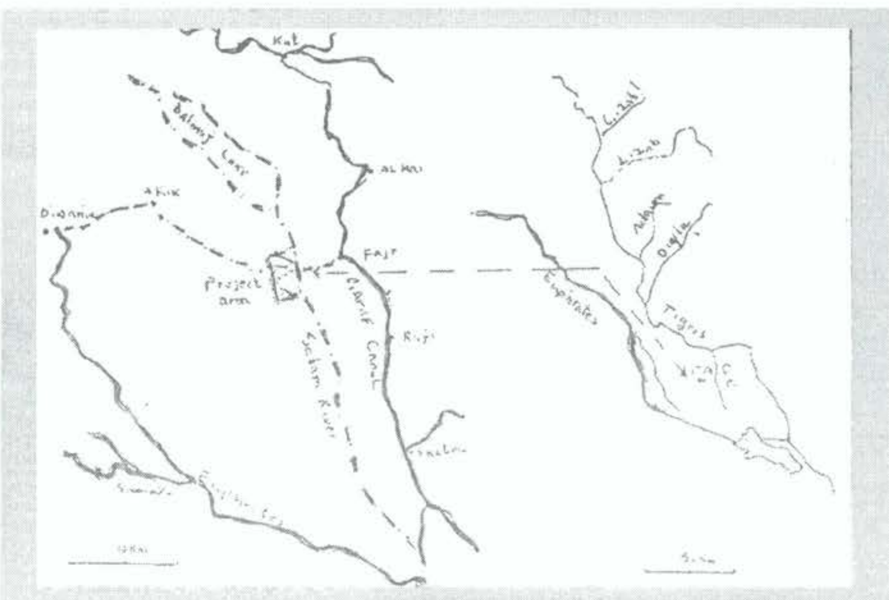

Figure 1. *Location map of the study area.*

and passed through 4.0 and 2.0 mm sieves. Air dry 0.84 mm in diameter were obtained using the rotary drying sieve method (4). Particle size distribution, salinity, carbonate and organic matter contents were measured using procedures outlined in Black, et. al..

2. Three soil plots, 10 x 250 metres in size, were selected toward the prevailing wind directions, namely west, north-west and north. Each plot was subdivided into five plots 10 x 50 m. Trenches, 15.0 cm in depth and 1.0 to 20.0 m in length were dug at locations indicated in figure 2. The trenches were used as sediment traps to collect the eroded soil material bi-monthly. The trapped sediments were weighed, air dried and analyzed as in step 1.
3. Sand traps (8) in triplicate sets were vertically positioned, in an open field, in the study area oriented towards west, north-west and north of the prevailing wind directions. Each set of sand traps included five different heights: 0, 5, 25 and 75 cm. Trapped soil materials were also collected bi-monthly, weighed, air dried and analyzed as in 1.
4. As proposed by Fryrear et. al., (9) was applied on the same soil samples of step 1, 2 and 3 to predict the percentages of erodible fractions.[1]

Results and discussion

Desertification features

The climate of the study area is an arid type having a very hot summer with a mild winter. The precipitation is erratic and falls between November and April. The differences in rain distribution from year to year, or within the same season, have a direct influence on the natural and cultivated vegetation and consequently on soil properties. The mean maximum June to September temperature exceeds 35°C. The minimum can go below 0° C in December and January (figure 3). Daily evapotranspiration (ETP) rates vary from 1.5 mm in the winter months, reaching their peak during the summer months with a value of 9.0 mm. The total yearly ETP value from the free water-table is around 2,000 mm (7, 8).

Wind speeds reached their maximum by midday in July. The average wind speed from three stations surrounding the study area was 3.3 mm/sec, predominantly north-westerly with 46.7 per cent, followed by west with 20.9 per cent and north with 16 per cent of the total wind direction (1). The measured threshold velocity for the movement of soil and sediment particles was 3.0 m/sec (1). Dust storms occur more frequently during spring and autumn, with an average of 20 days per annum. During the dust storms fine particles are blown away from the existing dunes plus the creeping particles along the wind path (12) causing

Table 1. Some properties of studied soils and dunes material (Experiment 1)

Sample sites	Sand %	Silt %	Clay %	Tex.	Ex dsm/m	CaCo %	O.M %	Agg.> 0.84 mm %
1 soil	9.0	53.0	38.0	SiCl	25.0	24.0	0.7	78.0
2 soil	10.0	56.0	34.0	SiSl	20.0	25.0	0.8	75.0
3 soil	12.0	60.0	28.0	Sil	23.0	24.0	0.6	68.0
4 soil	15.0	62.0	23.0	Sil	13.0	23.0	0.7	66.0
5 dune	28.0	48.0	24.0	Cl	4.0	27.	0.5	48.0

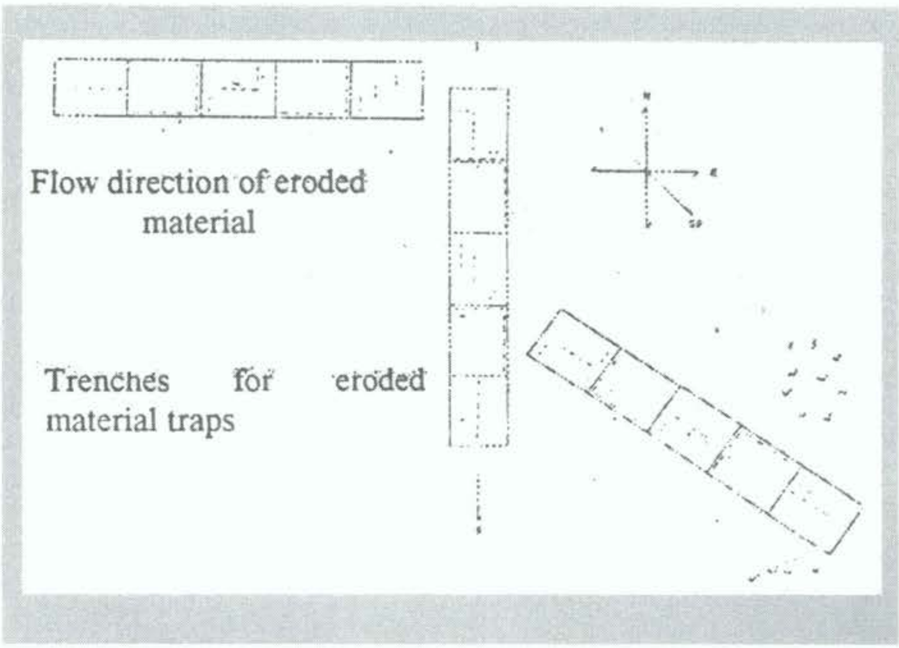

Figure 2. *Experimental setup monitoring movement of eroded material.*

1 *Erodible fractions (EF) = 29.09 + 0.31 sand + 0.17 silt + 0.33 sand/clay – 4.66 org carbon – 0.95 CaCo.*

Table 2. Calculated potential soil loss values in five locations (Experiment 1)

* Aggregate dia>0.8 mm		1	E1	E2	E3	E4	E5
range	Ave.			T/ha year			
70.0-82.0	78.0	6.7	9.4	6.6	11.2	No erosion	
71.0-79.0	75.0	13.5	17.5	17.5	23.7	6.7	6.7
59.0-72.0	68.0	31.4	34.5	34.3	58.7	13.5	11.2
62.0-69.0	66.0	35.9	46.6	46.6	79.3	29.1	29.1
43.0-54.0	48.0	93.0	102.3	81.5	138.8	81.5	81.3

*Average of 5 replica

significant damage to crops, irrigation and drainage canals and to health. The eroded soils among the sand dunes have very sparse natural vegetation, dominated by *Cornuleca moncautha* wherever there are thin aeolian sand sheets, otherwise *Siedlitza rosmarinus* thrives. In some cases both of these dominant plants come in association plus a few other companion types of natural vegetation (7). The soil of the investigation area is alluvial overlying older sediments of periodic flooding of both the Tigris and Euphrates rivers. The area comprises a nearly flat plain of medium to fine texture with a few exceptions of coarse texture. Part of the area is covered with sand sheets and dunes of different shapes and sizes (11). The texture of the soil ranged from clay loam to clay, where the silt size fractions are dominant followed by the clay fractions; the texture of the sand dunes ranged from loam to sand with fine to medium sand fractions being dominant (table 1). These soils are low in organic matter (< 1 per cent) and high carbonate (> 25 per cent). The structure is poorly developed with penetration resistance exceeding 1,100 kpa when the soil is air dried. The salinity of the soils and dunes varied from slightly to very highly saline. The infiltration rate and hydraulic conductivity was classified as moderately slow (7,8,10). Large areas in the region are covered with mobile sand dunes, which may constitute a source of eroded materials that may be deposited or moved to new locations along the path of the blown wind. These dunes, in the absence of proper management and stabilization, remain a continued threat to irrigation and drainage systems of the agricultural lands including the Saddam River in its central section.

Potential wind erosion

From table 2 the aggregate percentages larger than 0.84 mm ranged in diameter from 43 per cent to 82 per cent, with an average of 78 per cent in site 5. The calculated values using the general relationships between potential average soil loss in T/ha/year and the primary factors governing wind erosion (14) are shown in table 2.

The average values of soil erodibility of an open bare field ranged from no erosion to 138.8 T/ha/year loss in soil material, using climatic factors (c) from FAO equation (13). Potential erosion calculated by Abed (1) for nine locations along the Saddam River in the same area ranged from 43.1 T/ha/year for the original soil surface up to 55.9 T/ha/year for the loose material (sand sheets), with the highest values reaching 125.3 and 127.4 T/ha/year, the lowest values reaching 1.5 and 3.7 T/ha/year for the soil sand sheets respectively (1). Chepil (5) indicated that in all soil textures erodibility is inversely associated with the percentage of non-erodible aggregates as determined by rotary dry sieving.

Furthermore, clay particles tend to increase the water-stable aggregates greater than 0.84 mm in diameter, whereas silt particles tend to increase the water-

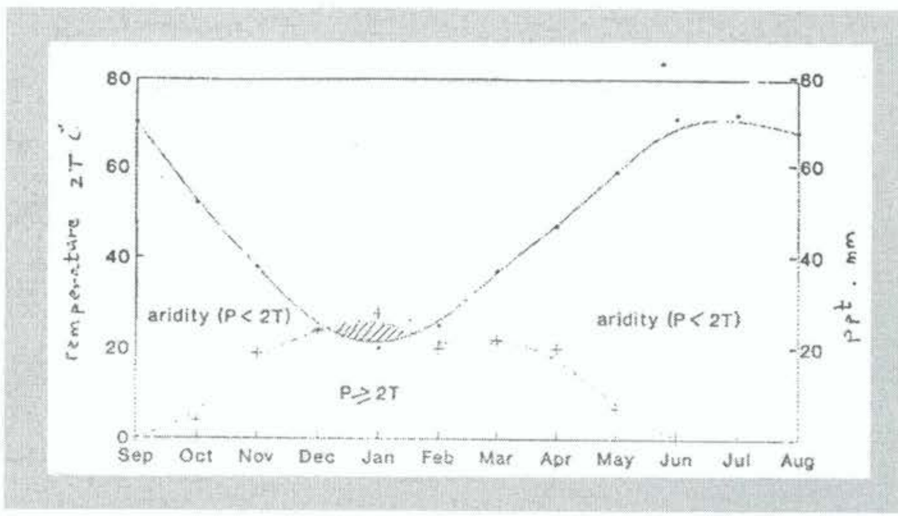

Figure 3. *Average monthly rainfall (-), and Temperature (+) for AL-Hai station.*

Table 3. Some properties of studied soils (Experiment 2)

Sample sites	sand %	silt %	clay %	Tex	Ec dsm/m	CaCo3 %	O.M. %	Agg>0.84 mm
north plots	17.0	56.0	27.0	Sil	31.0	25.0	0.6	77.0
north west plots	4.0	69.0	27.0	Sil	30.0	23.0	0.8	78.0
west plots	13.0	64.0	23.0	Sil	28.0	24.0	0.6	72.0

Photo 1: *Soil degradation caused by erosion in Northern Iraq.*

stable aggregates smaller than 0.02 mm in diameter, and both fractions, silt and clay, tend to decrease the erodibility by wind (5, 13). The effect of colloidal clay may be conditioned by the mineralogy and chemical properties of other constituents in the soil, such as salinity, carbonate content, ESP, etc. (4,9). Using the general formula proposed by Fryrear (9) on the studied soils the erodible fractions ranged from 16 to 32 per cent when salinity is not included (9). This means the stability of soils ranged from 68 to 84 per cent. The erodible fractions of this formula are lower then the equivalent erodible fractions based on aggregates 0.84 mm obtained by dry sieving. This could be related to the fact that the aggregate status of the soil at any time is the result of many aggregates forming and degrading processes. These processes comprise a complex physical and chemical relation. On the other hand, the present formula takes into consideration particle size distribution and some chemical properties. But this formula gives a fast estimation of the erosion potential comparable to the dry sieve method and could be applied on the available data in soil survey reports of Iraqi soils. Soil salinity becomes an important factor as it causes lesser vegetation cover. Consequently, lower organic matter content which, in association with CaCo3, acts as coating and bridging complexes around and between soil particles.

Actual wind erosion

The particle size distributions of the soils are significantly different from eroded materials collected in trenches (tables 3, 4). The texture class of the original inter-dune soil is silt loam with silt size particles dominant and ranging from 56 to 69 per cent. The eroded material was dominated by sand particles that ranged in quantity from 59 to 72 per cent as an average of five replica and three sites. The average sand, silt and clay particles in the original soils were 11.3, 64 and 25.7 per cent compared to 65.2, 20 and 14.8 per cent in the eroded materials. The weight of collected soil samples was variable from one location to another, from 6.2 to 11.1 kg/m/year. The highest quantity of eroded materials was in the north-west wind direction, followed by west and north. Statistical analysis showed significant differences among the average values obtained for three wind directions. The weight of yearly collected samples amounted to 10.56, 8.9 and 7.16 kg/m/year, which is equivalent to 105.6, 89 and 71.6 T/ha/year for the north-west, west and north wind directions. The results obtained by Abed (1) for the same area were 106.7, 95.3 and 78 T/ha/year for the same wind directions (1). The values obtained by Abed (1) are comparable to averages 3.1, 4.9 and 5.1 higher than in our investigation. These differences are probably due to wind velocity and the width of openings of the sand traps. The particle size distribution of the eroded materials were composed of 72.5, 14.3 and 13.2 per cent sand, silt and clay respectively, compared to 68.6, 165.1 and 15.3 per cent for the sand dunes. Whereas for the soils as averages were 25.3, 45.9 and 28.8 sand, silt and clay.

The results of potential and actual loss of soil material by wind calculated or measured indicated:

1. The severity of wind erosion in the study area;
2. The greatness of single soil factor as a texture effect or a composite soil property as soil structure on the soil loss in the area, assuming the environmental conditions being the same;
3. This is because particle size distribution of eroded material collected from the trenches or sand traps are quite different from the original soils and closer to that of the sand sheets and dunes;
4. Erosion occurring in the area is mainly from the loose material on the soil surface and of the existing dunes, which is directly exposed to the wind forces;

Table 4. Some properties of eroded material, Experiment 2

Sample sites	sand %	silt %	clay %	Tex	ecdsm/ m	CaCo3 %	O.M. %
North plots	59.0	24.0	17.0	Sl	28.6	26.0	0.5
North west plots	64.6	21.4	14.0	Sl	23.7	25.3	0.8
West plots	72.0	14.6	13.4	Sl	22.0	25.0	0.9

5. These materials in motion act as projectiles that cause further abrasion of the soil surface producing soil erosion. In fact, the criteria of the loose erodible material have been proposed for use in the new wind erosion prediction system (16);
6. A more reliable and technically sound procedure is need to predict the erodibility index with lesser physical measurements This would save time and money and provide a means to estimate the erodibility index on a regional basis.

Solution of the wind erosion equation predicts average annual soil loss from a given agricultural field. But the actual soil loss may differ if calculated for shorter periods or different seasons, because of variations in wind, velocity and precipitation from the average. It is recommended to measure soil moisture of erodible surface soils and the rate of evapotranspiration as a function of time and hydraulic properties of the soil loss values. The sand traps used in the study (8) proved to be useful in measuring the actual soil loss, therefore it should be extended to include other regions.

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Eco-Regeneration and Runoff Collection in Cholistan

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Introduction

Cholistan is an extension of the Great Indian Desert, which includes the Thar Desert in Sindh province of Pakistan and the Rajasthan Desert in India. Covering an area of 26,330 km^2, it lies within the south-east quadrant of Punjab province, between latitude 27°42' and 29°45' north and longitude 69° 52' and 73° 05' east (Arshad et. al., 1995; Jowkar et. al., 1996); 480 km long while its width varies from 32 to 192 km. The entire area is divided into two parts: Lesser Cholistan constitutes the desert margin consisting of a series of saline alluvial flats, alternating with low sandy ridges; its 20 per cent area comprises flat plains of hard clay, locally known as *Dahars*. Greater Cholistan is the name given to the southern part of the desert, which consists mostly of sand dunes, ridges and depressions.

The word Cholistan is derived from a Turkish word, *Chol*, which means a desert; some historians believe that this name has been distorted from an Iraqi word, *Chilistan*, meaning waterless waste land. Cholistan is popularly known as Rohi. In a dialect still spoken in some part of Tibet, *roh* means a hill, from which the name *Rohilla* has been attributed. In fact *Rohi* is derived from the Pushto word roh, meaning waste sand or a sandy desert (Auj, 1987).

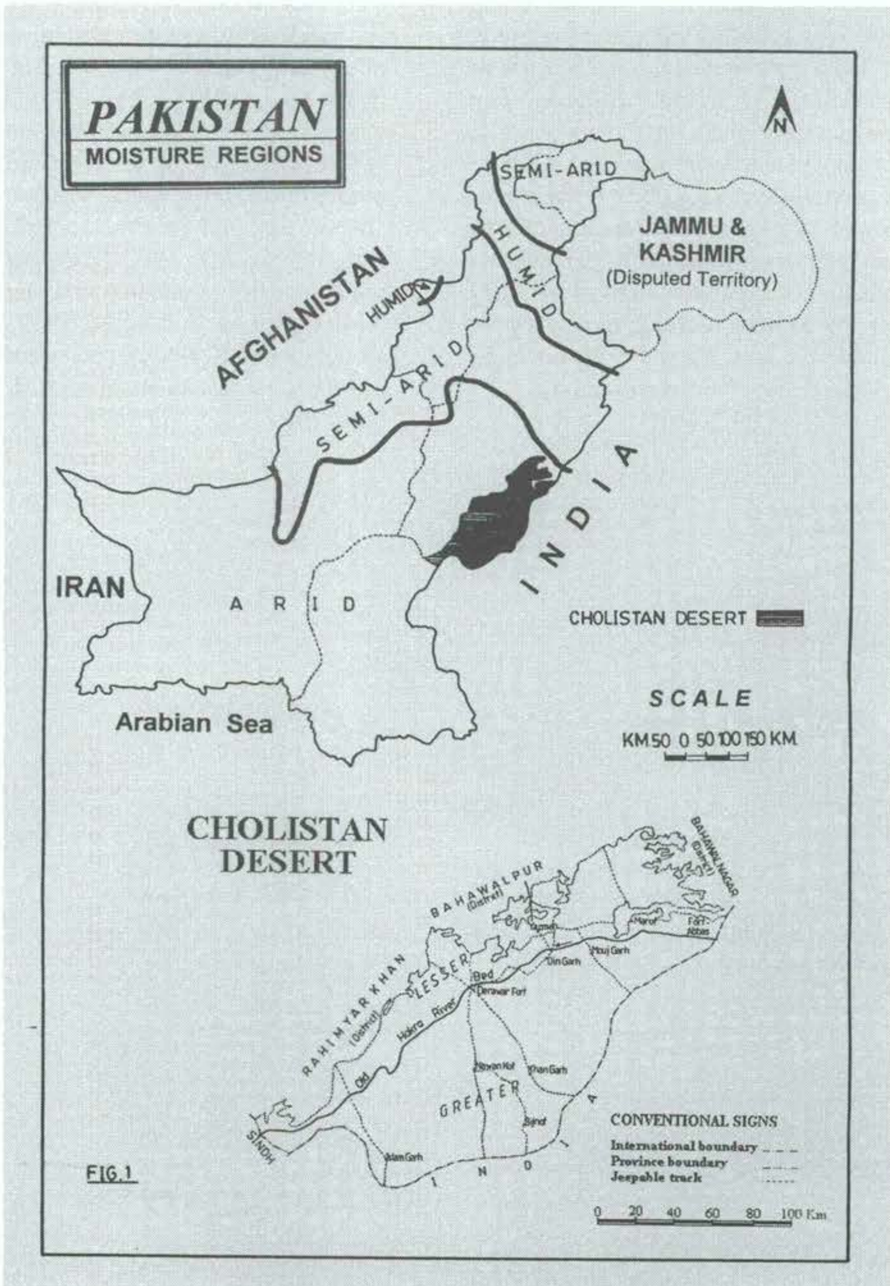
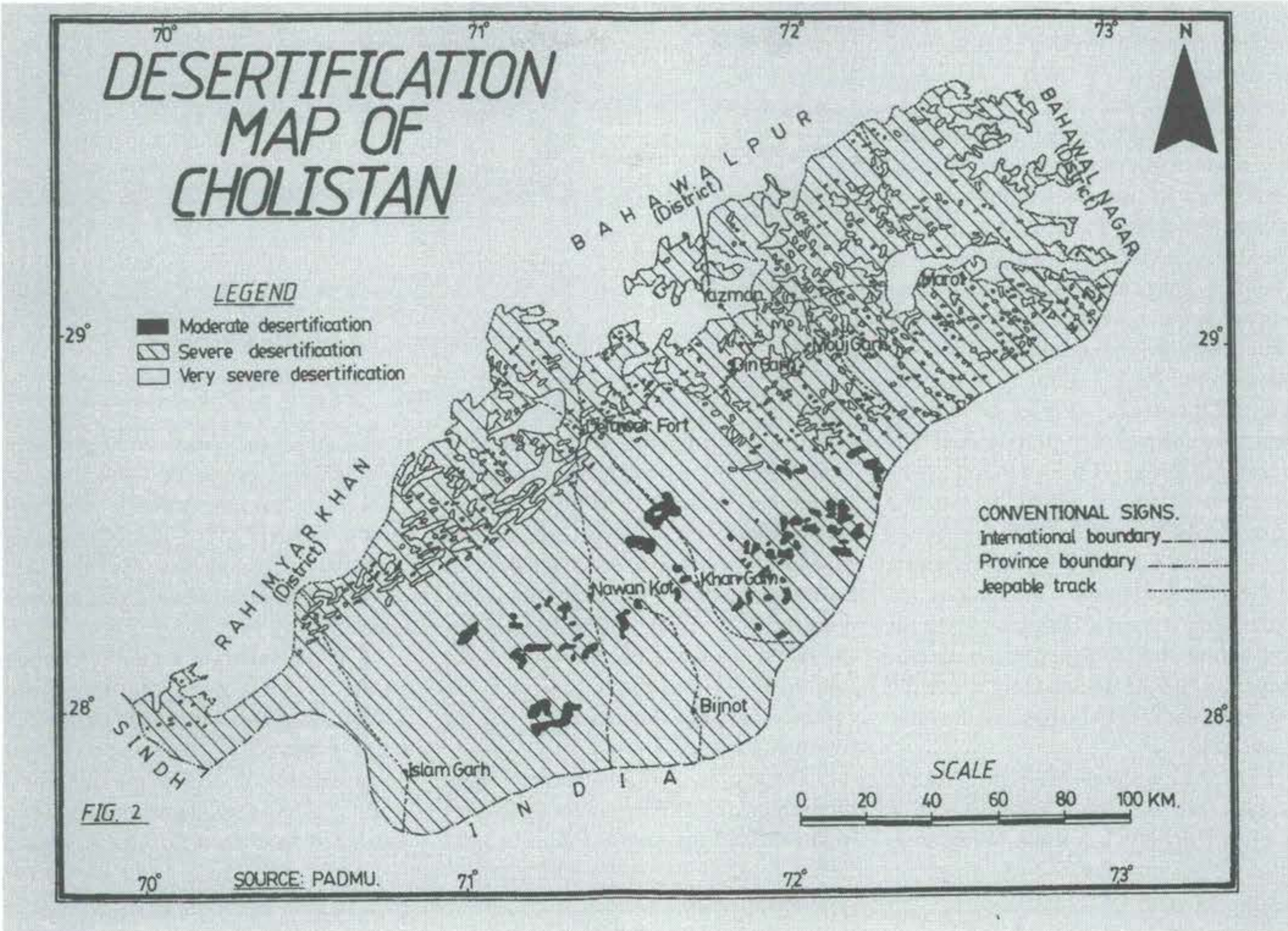


FIG.1



Cholistan: cradle of Hakra Valley civilization

Around 4000 BC Cholistan was a cradle of civilization commonly known as Hakra Valley civilization, when the Hakra river flowed through the region. The river supplied water until 1200 BC; about 600 BC the flow became irregular and consequently disappeared. The Hakra civilization that flourished was one of the longest in the course of world history. Aryans were the indigenous people and the earliest civilization of the Indian subcontinent. In cultural advancement it can be compared with the Babylonian, Egyptian and Mesopotamian civilizations. No one is sure how this great Aryan civilization vanished from Cholistan. Possibly a variety of problems such as hostile invading tribes, a change in the course of the river and depletion of irrigation facilities contributed to the ultimate disappearance of this great civilization.

The climate of Cholistan is arid (fig 1), a sub-tropical continental type, characterized by low and sporadic rainfall, high temperature, low relative humidity and a high rate of evaporation and strong summer winds. Most of the rainfall is in July and September but some also falls in winter. The annual rainfall varies between 100 to 250 mm, but may exceed 250 mm. The evapo-transpiration rate in the desert

Table 1. Extent of desertification

Desertification Class	Extent (ha)	%	Problems
Moderate	58,700	2.0	Wind erosion, vegetation cover, sodicity, and climatic condition.
Severe	2,079,400	81.0	Vegetation cover, soil physical properties, wind erosion and climatic condition.
Very severe	441,900	17.0	Sodicity, vegetation cover, soil physical properties.
Total	2,580,000	100.0	

Source: PADMU – Pakistan Desertification Monitoring Unit.

stands at 300 cm a year. This is ten times the rate of rainfall, making large tracts of the area extremely arid and barely habitable (fig 2 and table 1).

The people of Cholistan depend mostly on rainwater, which is collected in natural depressions or man-made ponds, locally called *tobas*, during the rainy season. There are more than five hundred *tobas* in Cholistan, not all of them suitably sited. As a result water is rapidly lost and some cannot be used for long periods. The *tobas* supply water for a maximum of three to four months. Major water losses from the *tobas* are seepage and evaporation. The cleaning of tobas is also not done regularly, which also reduces the water storage capacity (Akram et. al., 1995).

Extreme aridity, the predominantly sandy nature of the soils, topography and extreme deficiency of drinking water, as well as non-availability of fresh water for irrigation, are the main factors which did not allow the area to be used as an arable land (table 2).

Drinking water and storage of forage grasses are the main causes of low livestock yields in Cholistan. When there is no rain during the year, water and fodder become severe problems for the people and livestock. Because of drought, the people are compelled to leave the area in search of water and fodder and migrate towards irrigated lands, where they stay until the rains occur in Cholistan. After the rains, Cholistan becomes green and rich in forage grasses, and the carrying capacity of ranges increases as well as livestock production.

The people of Cholistan have three kinds of prayers: they pray for the clouds to appear and the rain to fall; when the clouds appear they pray for the wind not to blow, as it drives the clouds away; when rain falls and there is water all around, they pray for wind to blow as it dries the paths, so that the stranded caravans and herds of livestock can move again.

The precipitation required to yield runoff is known as the threshold precipitation. This varies with terrain and vegetation cover as well as soil characteristics. It is quite possible for a locality to have frequent light showers, which fail to exceed the threshold and

Table 2. Vegetation cover

Vegetation Cover	Extent (ha)	%
Good Vegetation (20 – 50%)	525,000	20.0
Moderate Vegetation (5 – 20%)	1,613,100	63.0
Poor Vegetation (<5%)	441,900	17.0
Total	2,580,000	100.0

Source: PADMU – Pakistan Desertification Monitoring Unit.

Table 3. Profile characteristics as a catchment for rainwater harvesting located about 125 metres north-west of Ramewala *toba*, in the vicinity of Dingarh, Cholistan Desert.

Soil Horizon	A	B	Cb	C1	Cg	C2
Soil depth (Cm)	0 – 6	6 – 34	34 – 67	67 – 90	90 – 110	110 – 150
Texture	Clay loam	Silty clay	Loamy very fine sand	Loamy fine sand	Loamy fine sand	Loamy very fine sand
Structure	Massive	Sub angular Massive blocky	Massive	Massive	Massive	
Pores	Common fine vesicular	No	No	No	No	No
$_pH$	8.8	9.0	9.0	8.8	8.8	8.8
Mottles	No	No	No	No	No	No
Roots	No	No	No	No	No	No
$CaCO_3$	Common very fine nodules	Common fine nodules	Common fine and a few lime kankers	Common very fine lime nodules	Common very fine lime nodules	Nil
Hardness	Hard	Very hard	Soft	Friable	Friable	Very friable
Clayed soil	No	No	No	No	Yes	No
Buried soil	No	No	No	No	No	No

Source: PADMU - Pakistan Desertification Monitoring Unit.

simply evaporate or soak away. Special treatments may reduce infiltration or render the surface hydrophobic and so make rainfall collection possible in localities with unsuitable soils; treatment can also improve the collection efficiency of existing, untreated catchments. The problem is to find and apply an effective, sufficiently cheap, durable and non-harmful compound (Hutchinson et. al., 1981).

Topographical form and runoff collection

The features of soil profiles from the north-west of Ramewala *toba* (table 3), in the vicinity of Dingarh Fort (Cholistan), show that the soil profile texture is clay loam to silty clay up to 34 cm depth, while up to 150 cm of the remaining depth of the profile consists of very fine loam and sand textures. The soil horizon (cb) from a depth of 34 to 67 cm is buried, and the soil horizon (cg) from a depth of 90 to 110 cm is clayed. The structure of the profile is between massive and sub-angular blocky characteristics. The pores in the top horizon (A) of the profile from the soil surface to six cm depth are common fine vesicular types. These pores are not continuous; therefore, infiltration of water will not be deep. The pores in other horizons of the profile are absent. The pH of the profile is between 8.8 and 9.0. Due to high sodicity in the profile, the soil horizons are devoid of porosity. Mottles and roots are also absent in the profile. The soil profile up to 110 cm consists of $CaCO_3$ in the form of common very fine to fine lime nodules and a few lime cankers that also cause hardness. The profile from the soil surface to a depth of 34 cm is hard to very hard. The horizon from 90 to 110 cm is clayed indicating that once it was under water, as a result there is no pore space. The characteristics of the profile indicate that the soils are non-porous, and non-drained to very poorly drained. It indicates that this area is very suitable for rain runoff collection.

The features of the profile located 2.37 km. from Dingarh Fort on Barianwala *toba* (table 4) track towards the west. Except for some features, the characteristics of this profile mostly resemble the profile under table 3. The depth of buried horizon is more and the profile does not contain clayed horizon. The profile consists of common very fine to fine mottles indicating that these soils once had been under water. This profile also indicates that the area in non- to very poorly drained is, therefore, very appropriate for rain runoff harvesting and collection.

The characteristics of the profiles show that the fine textured soil which lies in Cholistan with level to levelled topography is dense, impervious, non-porous to very poorly porous, non- to very poorly drained, saline-sodic, capable of generating maximum runoff after absorbing minimum water. The features and characteristics of the soil indicate that Cholistan is the best catchment area for rainwater harvesting and collection.

In Cholistan the catchment area lies adjacent to the fields on the same level, and is known as a micro-catchment

Table 4. Profile charcteristics as a catchment for rainwater harvesting located abot 2.37 km from Dingarh Fort on Barianwala *toba* track, about 500 metres toward the west of the track.

Soil Horizon	A	B	Cb	C
Soil depth (Cm)	0 – 8	8 – 35	35 – 90	90 – 150
Texture	Clay loam	Silty clay	Loamy very fine sand	Loamy fine to fine sand
Structure	Massive	Sub angular blocky	Massive	Massive
Type of pores	Vesicular	No	No	No
No. of pores	Common fine	Nil	Nil	Nil
$_pH$	8.8	9.0	9.0	9.2
Mottles	No	Yes	Yes	Yes
No. of mottles	Nil	Common fine to very fine	Many fine	Many fine
Roots	No	No	No	No
$CaCO_3$	Common fine lime nodules	Common fine lime nodules	Common fine to a few medium kankers	Common very fine lime kankers
Hardness	Hard	Very hard	Friable	Friable
Clayed soil	No	No	No	No
Buried soil	No	No	No	No

Source: PADMU - Pakistan Desertification Monitoring Unit.

system. The runoff water flows only a short distance. Micro-catchment systems are effective for use in growing trees and shrubs (Pacey et. al., 1986) and are also effective in collecting water and precipitation.

It is a matter of concern for the environmentalists that Pakistan's precious land resources are subjected to severe land degradation and desertification. Controlling the water lost by evaporation is one of the most cost-effective methods of maintaining adequate water supplies and should be an integral part of any open-top water storage facility. Although relatively expensive, a roof over the storage is an effective means for controlling evaporation. Floating covers of low-density synthetic foam rubber are effective for controlling evaporation from vertical walled, open-topped storages. Evaporation control on ponds or reservoirs with sloping sides is difficult to implement because the water surface area varies as the depth of water changes.

Ecological restoration

It is essential that land-based activities, aimed at combating desertification, restoration of the ecological balance by utilization of rainwater and improvement in the rural economy by creating stable resource-based and increased employment opportunities, the involvement of participating people in decision making is essential if the needs and interests of individuals and institutions concerned are to be fulfilled. Such programmes require a comprehensive and relevant policy, together with an administrative and technological framework which will promote programme efficiency through the effective tackling of all inter-related social, economic and environmental issues which prevail in the society by involving local communities in the process of combating desertification and restoring the ecological balance (Farooq, 1998).

Strategic interventions

Local availability of natural resources is declining and increasing demands are made on the remaining resources, so the cumulative impacts on environmental and social system are severe. This has meant a contentious cross-section of society, as local economic demands for water, grass and fodder expand. Resolution of these conflicts requires new perspectives, which combine social, economic and environmental concerns with an approach to habitat protection and biodiversity conservation. As a society, we tend to address desertification by using management technology and administrative means while relying on incomplete or inadequate information. To monitor an accelerating desertification problem, it is necessary to promote systematic and successive studies by applying improved rainwater conservation techniques.

The ecological balance of nature in this tract is seriously upset and poses widespread environmental degradation and resource depletion. The only viable scientific solution for recovery and development of resources would be a policy rooted in integrated approach, making sure that the technology deployed is appropriate to local conditions and is conservation oriented.

Discussion and results

From the foregoing, it is perceived that topographic form is the main factor which plays a vital role towards the development of the Cholistan desert as rangeland. Various relief positions control the occurrence of soils and the availability of moisture for vegetation growth. For example, in the southern region (Greater Cholistan), ridges invariably contain sands which have very low water-holding capacity, while the inter-ridge depressions or old channel beds contain loamy sands, sandy loam or loam with good water-holding capacity. The type of depression also plays an important role in rangeland development. The old Hakra bed acts as a drainage way for the area and collects most of the runoff. The soil of such channel bed is mostly sandy loam with moderate water-holding capacity. The availability of moisture in the channel provides greater support for grasses and legumes as supplementary fodder. This area is suitable for raising cattle due to its favourable relief and availability of drinking water.

The analysis of the Cholistan desert helps us to know that the desert tract is full of vegetation resources that can be exploited on commercial basis. Emphasis will be given to wild plant resources that may be used as supplementary food items having economic utility value as fodder, fuel, medicine and industrial utilization.

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Land-use Compatibility Index for Assessing Agricultural Sustainability in Uromieh, Iran

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Introduction

Problem formulation

In Iran, more than 50 million hectares (mha) (30 per cent of the total surface of the country) are affected by degradation; 12 mha of which are in a very severe status and some 5 mha are covered by active sand dunes.

This article presents some results of a study carried out in the north-west of Iran, in an area where sustainability seems questionable. Mismanagement of agricultural systems, overgrazing and converting rangelands into croplands are a few examples which have caused degradation, themselves symptoms of unsustainability.

As a result of increased populations and the shortage of arable land, much of the rangelands are converted, regardless of their suitability. Converting grazing areas, in an area where animal husbandry is a common practice, indirectly means overgrazing of the remaining, often poor quality, rangelands. This mismanagement has disrupted the natural equilibrium. Besides, as a result of soil structure deterioration, infiltration and permeability are badly influenced, to the extent that heavy rain easily leads to destructive floods. This obviously increases the sediment load of the Shahr-Chay river which, if it continues, will endanger the recently planned dam on the river. On the other hand, farmers resist any change in the present land use. The question which arises is how to assess the sustainability of current agricultural land-use types, using the land-use compatibility index (LUCI.

Methodology

The compatibility of land with its use explains the degree to which a land-use type agrees with the land suitability class. The land-use compatibility index (LUCI) is used to demonstrate the result of matching between land suitability classes on a suitability map and the way these units are used (fig 1).

GIS facilities help to integrate various information layers and to present the results. Land-use map units often cannot be matched directly with land evaluation and/or administrative map units, as the different information layers are not necessarily identical. For instance, land-use boundaries may not correspond with those of soil, vegetation or lithological map units. If the land-use type (demand) is satisfied by the supplier (the land), the land unit (LMU) on which the land use occurs is S1, in which case its suitability coefficient will be 1. Following this convention, S2, S3 and N will be scored 0.67, 0.33 and 0.1. Multiplying each coefficient by the extent (surface area) of

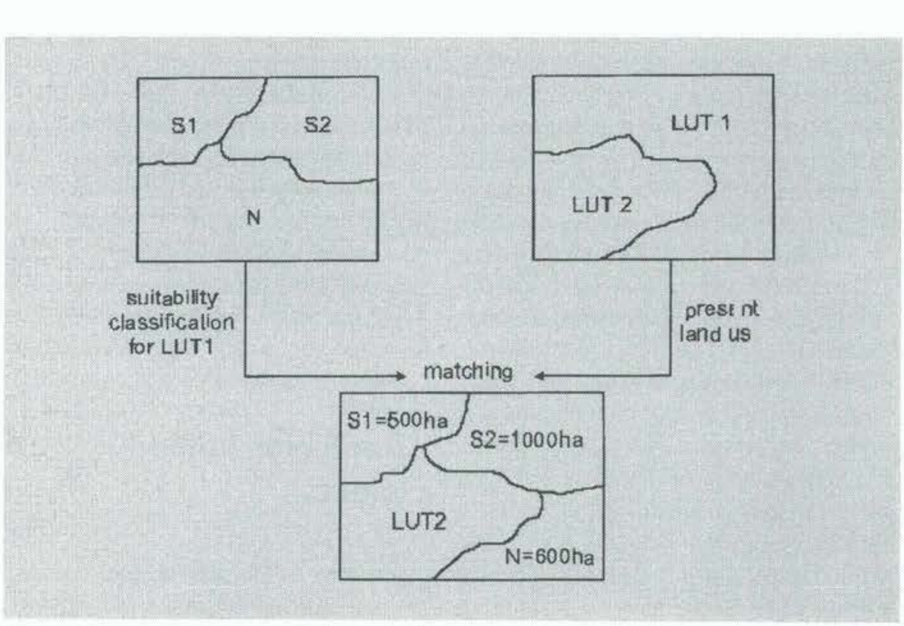

Figure 1. *Land use compatibility calculation.*

the land use, and dividing it by the total surface area of the related LMU, yields a coefficient for each land map unit. The final compatibility index for a given LUT would be sum of the coefficients of all LMUs, where the LUT (under consideration) is practised (see 'Calculation of the Land-Use Compatibility Index', p 5).

The compatibility coefficient can be written as: cx= ax * Si / A, where: cx= compatibility coefficient of LMUx for LUTi; ax= surface area of LUTi; Si= suitability coefficient of LMUx for LUTi and A= surface area of LMUx.

The compatibility index is then calculated using Cx= $\sum$ cx, where: Cx= land-use compatibility index of LMUx and $\sum$cx= total compatibility coefficients of LMUx for all of LUTs.

In this study, three classes were used, namely sustainable (rating >0.6), warning (0.3-0.6), and unsustainable if the rating was <0.3.

Land resources

The study area climate is characterized by cold and moist winters and mild summers; mean annual rainfall of about 590 mm; a mean annual temperature of 9∞C with a mean annual evaporation of 919 mm. The Shahr-Chay river, with a mean annual discharge of 5.3 m^3/s, is the most important surface water resource.

Geopedologically, the catchment consists of mountain, hill and piedmont, plateau and valley. Metamorphosed rocks occur in the western mountains whereas the rocks in the east are sedimentary. More than 35 per cent of the total area has a slope of 40 per cent and more. A total of 27 physiographic units were obtained, resulting from subdividing the five landscape units. The soils were classified at the family level (USDA, 1996) and the soil/physiography relationships are best explainable at that level. In general, entisols (lithic xerorthents and typic xerorthents) occur in the mountains and valley landscapes, whereas inceptisols (typic and lithic xerochrepts) are dominant in the extensive piedmont, covering a large portion of the central part of the study area, and alfisols (vertic haploxeralfs) in the plateau. In the fan, extensively stretched in the piedmont landscape, typic xerofluvents occur in the apical and fluventic xerochrepts in the distal section of the fan.

Land use

Animal husbandry and farming are the main activities of most of the 8,000 inhabitants of the area.

To identify present land use, a 1990 Landsat TM image was used. A known problem in mapping land use in areas where traditional agriculture is dominant is that of the 'mixed pixels', originating from small parcels as compared to the Landsat resolution. To solve this, at least to some extent, the resultant images from applying both PC and NDVI techniques were combined. A second problem was that the mature (about to be harvested) rainfed crops and the rangelands of fair quality, showed similar reflectance and were frequently classified as one and the same land-use class. Knowing that farming was not practised in the western high mountains, and that all areas classified as rangelands in the eastern moderately high hills are under dry farming, the study area was accordingly divided in two parts. A supervised classification of the image was carried out separately for the two parts and then merged. The obtained (present) land-use map, with eight classes, was cross-checked against field observations, visual interpretation of the hard copy of TM false colour image and that of Cosmos true colour image.

Interpretation of the 1956 aerial photographs (40 years earlier), followed by field inventories, yielded the past land-use map. Although only the major land uses could be mapped in this way, the change in land use since 40 years was satisfactorily extracted. A surface area of 3,445 ha, that is, 84 per cent of the total area was covered by rangelands and the remaining surface area was cultivated.

Monitoring land use changes

According to the present land-use map, 59 per cent of the total surface area is covered by poor range and only 17 per cent (6,050 ha) is farmed. In comparison with the past, the dry-farmed area shows a clear increase of about 6 percent, while rangelands, irrigated and partly irrigated areas have decreased in surface area. The decrease in irrigated land is probably caused by the decrease in the amount of water.

As a result of crossing the land-use map with the gradient map the following conclusions were obtained:

1. Sloping areas are more and more used for cultivation crops; 2. 3,470 ha of rangeland is converted into rainfed agriculture;
3. 2,465 ha of rainfed agriculture is converted into poor rangeland;
4. 1,020 ha of irrigated and partly irrigated land are now used as poor rangeland;
5. About 440 ha of rangeland are converted into irrigated and partly irrigated land;
6. More than 50 per cent of the total surface area is covered by poor rangeland.

Land degradation and evaluation

The revised Universal Soil Loss Equation (RUSLE) was used to determine the status of erosion in the study area. Based on the results and regarding the present land use, some 30 per cent of the land (about 12,000 ha) is seriously endangered (moderate and high erosion hazard classes). The remaining 70 per cent also suffers from slight erosion. The highest erosion rate is, notably, in the areas where rangeland has been converted into dry-farmed cultivation.

The software package ALES, Automated Land Evaluation System (Rossiter and van Wambeke, 1990) was used to determine the land suitability for the pre-selected five land-use types (LUT). LUT1 (tree plantation inter-cropped with alfalfa), LUT2 (alfalfa followed by summer crops/ wheat) and LUT3 (wheat/barley followed by hay production) were selected to represent semi-mechanized irrigated farming, while LUT4 (wheat/peas followed by barley)

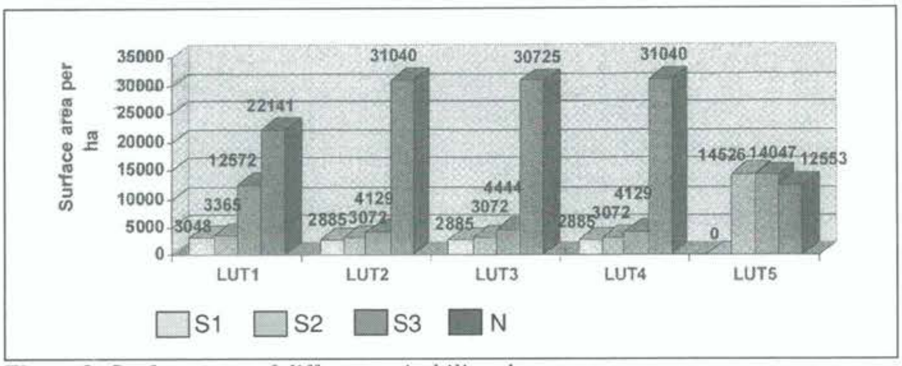

Figure 2. *Surface area of different suitability classes.*

represents semi-mechanized rainfed farming. Finally, LUT5 (sedentary pastorals) was selected to represent grazing activities in the area (fig 2).

Calculation of the Land-Use Compatibility Index

To calculate the Land-Use Compatibility Index (LUCI), the land use-map was crossed with the different land suitability maps, separately. In this way, the distribution of each land utilization type (LUT) with its corresponding suitability within each land-map unit was identified. For example, the surface area that is occupied by LUT1 (fig 1) within a given land map unit (LMU) is calculated. This surface area is multiplied by the suitability coefficient of the corresponding LMU. In order to obtain the compatibility coefficient of the LUT1, the result is divided by the surface area of the LMU (2,100 ha). The compatibility index is the sum of the compatibility coefficients.

S1: 500* 1.00/2100=0.24 }
S2: 1000*0.67/2100=0.32}
0.24+0.32+0.00= 0.56—
Compatibility Index
N: 600*0.1/2100=0.03 }

Results and discussion

The way the LUCI is calculated here is an attempt towards a simple quantification. Sustainability, the way it is introduced here, obviously is not meant to be applied to a single farm, but at regional or catchment level, under extensive agriculture. To assess agricultural sustainability, both biophysical and socio-economic components have to be considered (Farshad and Zinck, 1993; Zinck and Farshad, 1995). The compatibility between the ongoing LUTs and the suitability class is meant to cover the biophysical aspects. The factor of extent or surface area is to represent some of the socio-economic aspects in the study area, such as farmer skill with cropping systems, food demand, markets, and, to a certain extent, population pressure.

Considering the results, the lowest LUCI is 0.1 and the highest is 1. The LUCI status for the catchment under study is:

- 42 per cent of the study area is classified as 'unsustainable';
- 20 per cent fall under the warning class;
- 38 per cent is rated as 'sustainable'.

This means that some 60 per cent of the total surface area is in a fragile status. On the other hand, the average LUCI for the whole area is 0.39, that is, in the 'warning' zone (fig 3).

Theoretically, there should also be a relationship between the calculated LUCIs and the erosion status (in LMUs). The regression analysis shows a weak relationship (R= -0.27, P= 0.17.and N-27). The reason probably lies in the fact that the suitability of some of the LMUs, particularly those of the western mountainous rangelands is determined using grazing capacity as the main land-use requirement. To assess this land quality (grazing capacity), 'stocking rate' is used, which probably is a wrong indicator, simply because not all vegetated areas have high grazing capacity, taking palatability into account. Through a comparison between the present land use map and the erosion map, it is revealed that erosion rate in the western parts is low because of a relatively good vegetation cover.

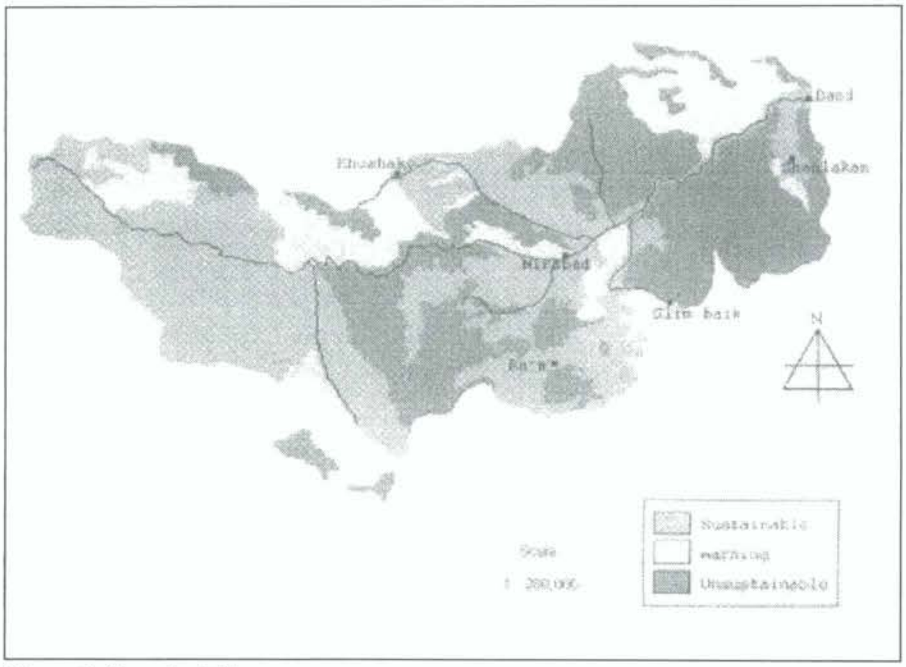

Figure 3. *Sustainability map.*

But, according to the land suitability classification, these areas are classified mainly as 'not suitable' for most of the defined LUTs. When these LMUs are excluded a reasonable relationship between land degradation and LUCI ($R= -0.53$, $P= 0.01$ and $N=20$) was obtained.

Conclusion

At present, the fate of agriculture in the Shahr-Chay catchment is uncertain and rather alarming. Present-day agricultural systems cannot satisfy the needs of the fast growing population. The low agricultural inputs, low production, converting grazing lands into rainfed farms, over-grazing of available rangelands, farmers' lack of or poor knowledge of soil conservation, weak techniques of water harvesting and the water recharge are factors that have made these systems unsustainable. A land-use plan supported by inhabitants of the area can rescue the current situation.

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Degradation of Forest Reserves in Zambia: A Case Study of Muyama in Central Zambia

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Introduction

In many developing countries, such as Zambia, forest policy (FP) was introduced during the colonial period when the State placed certain forest areas under permanent government control to:

1. Protect land against floods, erosion and desiccation and to maintain flows in rivers;
2. Supply timber at economic rates to industries and where possible to maintain a stable export trade;
3. Supply the forest produce required for subsistence of local people;
4. Promote the practice of sound forestry and an appreciation of the value of forests including the protection of biodiversity resources of flora and fauna among local people (NRG, 1961, p1.).

These objectives were pursued through forest surveys, enactment of laws and the training of forest staff to police the communal and protected areas.

This forest policy was inherited at independence although the indigenous people did not completely accept the approaches to forest conservation. Apparently the establishment of forest reserves was perceived by local people as a mechanism to exclude them and their traditional institutions from making decisions over natural resource management. Tewari (1996) has made a similar observation concerning the introduction of forest policy in India by the British colonial government.

The growing pressure on forest resources caused by population growth and natural disasters (such as drought which has contributed to increased rural migrations) is now manifest through encroachment on forest reserves throughout Zambia. This article, therefore, discusses the problem of degradation of Protected Forest Reserves through human encroachment in Zambia. A study in the Muyama Forest Reserve in Chibombo District Central Zambia (fig 1) was used to assess the temporal and spatial dynamics of human induced degradation in a forest reserve that has become widespread in Zambia today.

The selection of the Muyama Forest Reserve was justified because Chidumayo and Aongola (1998) show that the pressure to convert forests into agricultural land, in areas under customary tenure controlled by chiefs, is high especially in the hinterlands of urban areas where about 45 per cent of the Zambian population live (GRZ, 1990). Wood (1983) has shown that the total population of Zambia was 3.5 million in 1963, 4.0 million in 1969, 5.7 million in 1980 and 7.8 million in 1990. The figures represent annual growth rates of 2.5 per cent between 1963 and 1969, 3.1 per cent between 1969 and 1980 and 3.2 per cent between 1980 and 1990 (GRZ, 1990). Muyama is, therefore, suitable since it is in the hinterland of Kabwe urban to the north and is centrally situated in the country.

Forests in Zambia cover 7.23 mha and the major causes for the conversion of land use from forests are population growth and internal migrations, especially from Southern Province to Central Province resulting from the severe droughts of the 1990s (Chidumayo and Aongola, 1998; Siame, 1997). Traditional chiefs often allocate land in forest reserves to supplement land held under customary tenure which is said to be insufficient. Forest reserves are used because they are often considered to be abandoned 'common property' resources alienated by the State against the wishes of the local communities.

An attempt has been made to classify forest reserves in Zambia according to threats to their integrity as conservation areas (table 1). Encroached reserves due to settlement and uncontrolled harvesting of timber and wood fuel represent about 16.0 per cent of the reserves in Zambia, while 3.2 per cent are depleted due to deforestation (complete removal of forest cover). The latter is increasing at an unprecedented rate. The rest of the forest reserves are relatively secure, of which 39 per cent are surrounded by areas with high population density which have been classified as threatened. Exotic forest

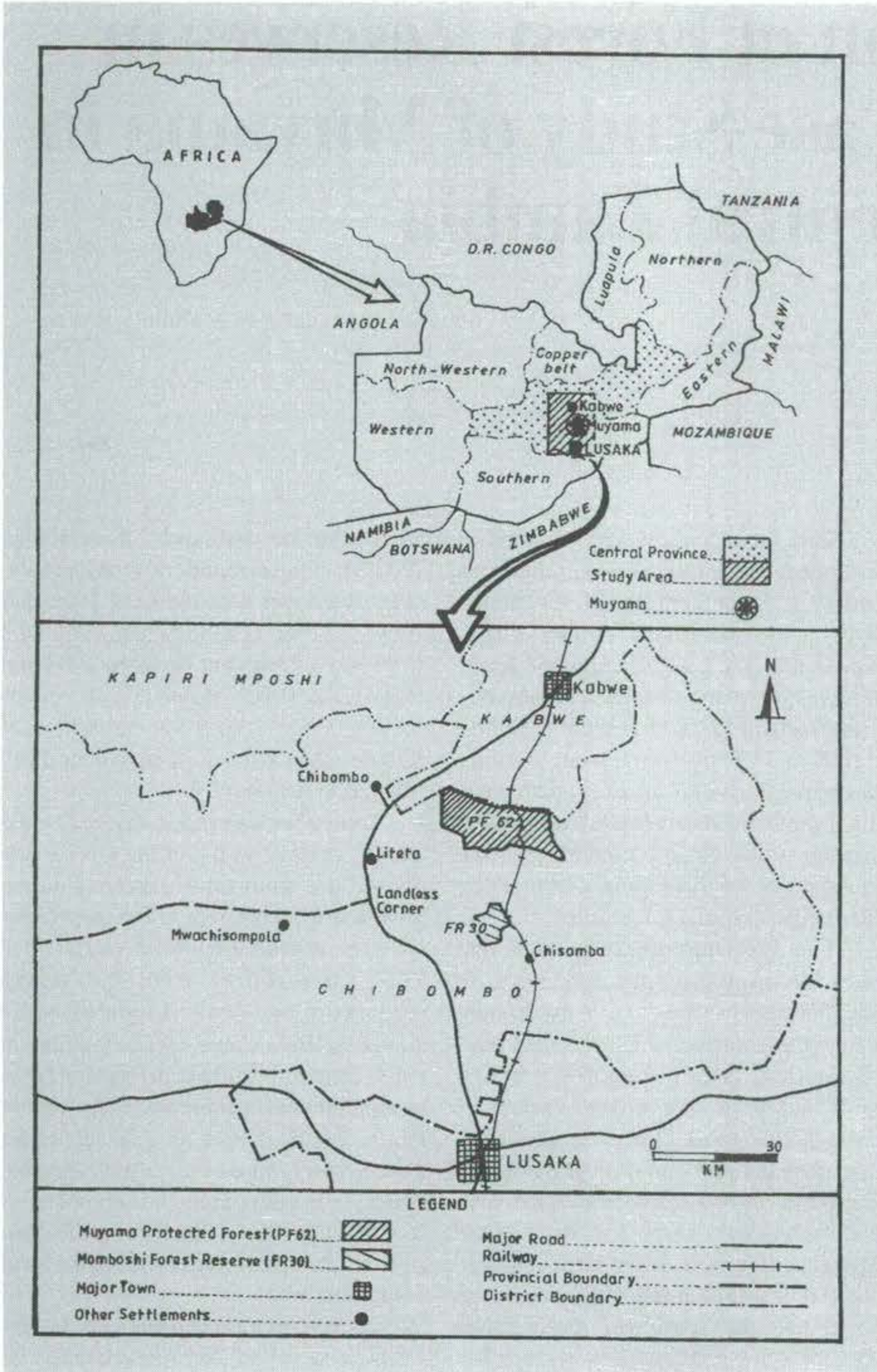

Figure 1. *Location of the study area – Muyama Protected Forest, Chibombo. District (Kabwe Rural) Central Zambia.*

plantations have been established in some depleted forest reserves (Upgraded Forest Reserves), but these constitute only 5.0 per cent of all the reserves in the country.

The study area

The Muyama Protected Forest covers an approximate area of 30,000 ha and is located between longitude 28° 14' and 28° 30' East, and latitude 14° 35' and 14° 45' South in Chibombo district in Central Province. The western part of the reserve which was studied falls under the jurisdiction of Senior Chief Liteta of the Lenje people, while the eastern part is in Chief Chamuka's area. The two parts are separated by a railway line.

Average annual rainfall for Kabwe, which is just north of Muyama, is 957 mm, and the reserve is covered by sandveld soils which are widespread in Chibombo district. Although normally acidic, deeply weathered, low in organic matter and leached, they respond well to fertilizers, and are suitable for growing maize and other crops, and for livestock raising (GRZ, 1989). Within the reserve, dambos, which form drainage strips, are quite common and are used mainly for dry season grazing and occasionally for vegetable gardens on dambo margins where the water-table is close to the surface. Tree cutting for agriculture takes place on the interfluves.

Population data for Chibombo district is not available. However, the total population for the former Kabwe Rural District (from which Chibombo was demarcated in 1997) was 219,865 by 1990, and it had population densities of 4.8; 5.7 and 8.5 persons per km^2 in 1969, 1980 and 1990 respectively (GRZ, 1990, p 3 and p 11). The population density in the Muyama Forest Reserve and the surrounding areas for 1990 is given in table 2.

According to the preliminary estimates of the Agricultural and Pastoral Production Survey for small and medium scale farmers for 1996 to 1997 by the Central Statistical Office (CSO, 1997), Chibombo district is a productive agricultural area. For instance, it produced 280.6 tonnes of sunflower out of a provincial total of 390.8 tonnes, which was 71.8 per cent of provincial production; it also produced 998.0 tonnes of groundnuts out of a provincial total of 2,476.6 tonnes equivalent to 40.3 per cent; and further harvested 25,193 tonnes of maize out of a provincial total 86,820

Table 1. Conservation status of Forest Reserves in Zambia.

Province	Forest Reserve No.	Distribution (per cent) of forest reserves by status				
		Intact	Threatened	Encroached	Depleted	Upgraded
Central	35	2.9	51.4	42.8	0.0	2.9
Copperbelt	51	13.7	25.5	25.5	9.8	25.5
Eastern	78	39.7	52.6	6.4	0.0	1.3
Luapula	23	30.4	52.2	8.7	0.0	8.7
Lusaka	14	0.0	14.3	21.4	64.3	0.0
Northern	44	18.2	45.5	31.8	0.0	4.5
North Western	62	71.0	21.0	6.4	0.0	1.6
Southern	34	29.4	41.2	26.5	0.0	2.9
Western	91	52.7	40.7	5.5	0.0	1.1
Zambia	432	36.1	39.4	16.2	3.2	5.1

(Source: Chidumayo and Aongola, 1998)

tonnes or 29.0 per cent. Out of this production, 82 per cent of sunflower, 38 per cent of groundnuts and 38 per cent of maize was marketed for cash.

Methods

In order to assess temporal/spatial trends in encroachment in the forest reserve, aerial photographs for 1982 and 1988 were analysed and a land-use map was prepared. During fieldwork conducted in October and November 1998, the 1988 photo mosaic was used for ground truthing that resulted in the production of an up-to-date land-use map of the forest reserve (fig 2).

Semi-structured interviews were held with 44 settlers (mostly heads of households) consisting of 25 men (56.8 per cent) and 19 women (43.2 per cent). The sampled settlers were intentionally drawn from eight of the 20 villages in

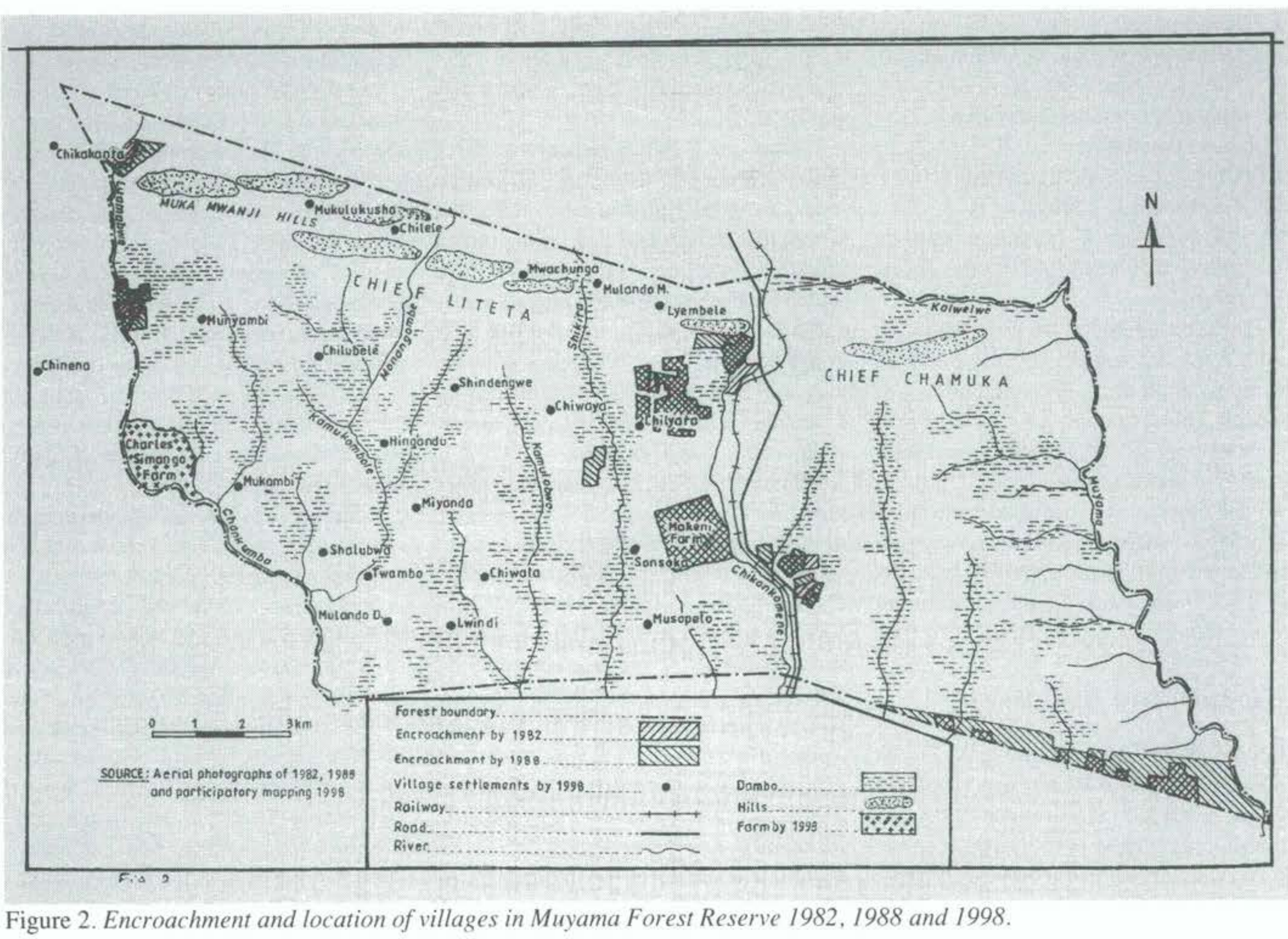

Figure 2. *Encroachment and location of villages in Muyama Forest Reserve 1982, 1988 and 1998.*

Table 2. Population density in Muyama Forest Reserve and the surrounding areas (1990).

Area	No/sq km
Muyama West	6.69
Muyama East	12.27
West of Reserve	21.29
East of Reserve	22.47
South of Reserve	4.99

(Source: Census supervisory Areas/CSO, 1990 Map)

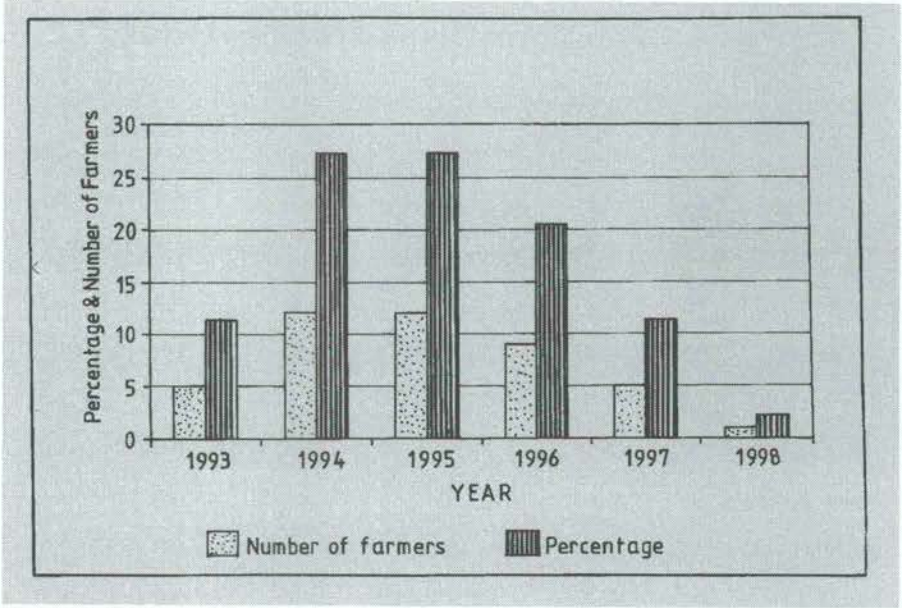

Figure 3. *Settlement in the Muyama forest reserve by sampled settlers.*

west Muyama under the jurisdiction of Chief Liteta. For each respondent, the following data were recorded:

1. Marital status;
2. Number of children;
3. Educational attainment;
4. Tribe;
5. Date settled;
6. Origin and reason for settlement;
7. How settlement was facilitated;
8. Income generating activities;
9. Assets owned;
10. Crops grown and marketed;
11. Food security status;
12. Views on how resources can be sustainably managed in the forest reserve.

In addition, meetings were held with a total of 102 settlers (89 men and 13 women) including seven headmen at which the concept of joint forest management as well as the new forest policy were discussed.

Literature review was also undertaken in order to obtain population density data from the 1990 Census Supervisory Areas (CSAS) in Muyama and the surrounding areas.

Results and discussion

Encroachment into the Muyama Forest Reserve started in 1976 when Headman John Chindalo Chilubele with 25 households settled in the forest reserve. Eviction of settlers by the Forest Department based in Kabwe occurred in 1979, but these were unsuccessful although the son of the headman was taken to Kabwe where he was tried and subsequently imprisoned for 32 days in 1981. However, major encroachment in the Muyama Forest Reserve is of recent origin. Most settlements started in 1994 and trends since then are summarized in fig 3.

Since each settler requires land for cultivation, encroachment has led to clearings in the forest reserve. Often the wood in cleared areas is converted to charcoal for sale to raise income with which to purchase food and inputs such as seeds and fertilizers. This process is continuing as new settlers are being accepted into the area. There is, therefore, a steady transformation from forest reserve to agricultural land.

The majority (27 or 61.4 per cent) of the sampled settlers stated that they came to settle into the forest reserve in search of virgin agricultural land from within rural Chibombo, especially from villages near Liteta Hospital and around Chibombo township, where population densities in the Census Supervisory Areas reach 94.59 and 57.22 persons per km^2 respectively. These pressures for encroachment are probably a result of the relatively higher densities of population around the Muyama Forest Reserve, as shown in fig 4. Other settlers came from outside Chibombo. Of these, 18.1 per cent and 20.5 per cent came from Southern Province and urban areas respectively.

The ethnic composition of the sampled settlers was diverse, representing twelve different Zambian tribes – thus making a microcosm of Zambia and reflecting in-migrations into the area. The local Lenje people constituted the majority, and represented 38.6 per cent of the sample. They were followed by their sister ethnic group, the Tonga, comprising 25.0 per cent of the sample. The majority of the settlers (72.7 per cent) were in the productive age group of less than 50 years of age with an average of 5.9 children per household. Large households mean that more grain has to be reserved for food instead of being sold for cash, and that there are many settlers in the forest reserve with corresponding demands on available natural resources.

The procedure of settlement was quite orderly. The men who came to establish villages were given permission to settle in the forest reserve after approaching Chief Liteta. The Chief would then refer each case to the ten-man chief's land allocating committee. The committee then allocated portions of the reserve to each village, setting boundaries based on physical features such as hills, streams and dambos. Then each settler approaches a particular headman who allocates a portion of his village land to an individual. Because the chief and headmen grant permission to settle, the process is orderly and traditional authority is strongly felt

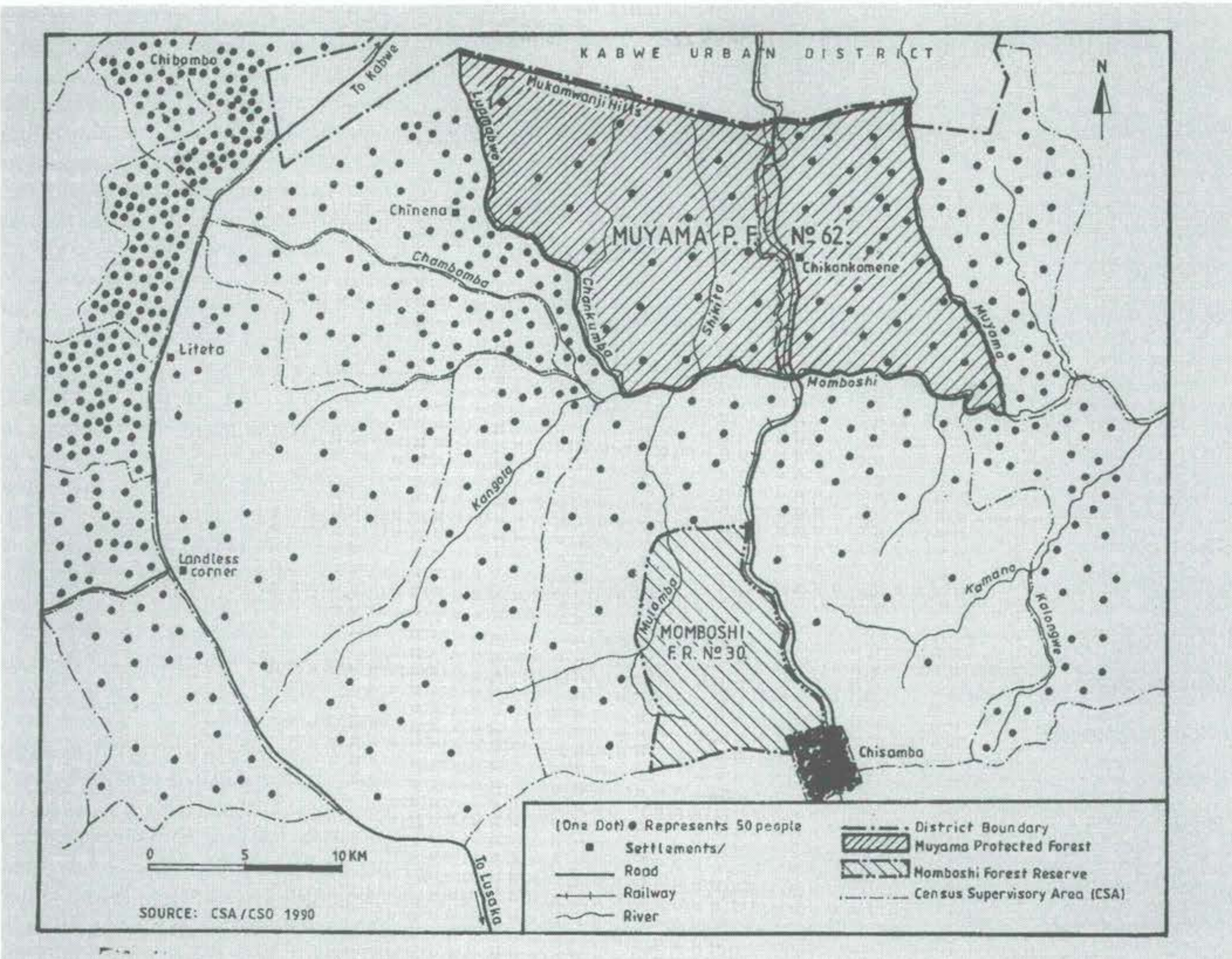

Figure 4. *Population density in Muyama and the surrounding areas by 1990.*

and respected by some of the sampled settlers/squatters.

Encroachment into the Muyama Forest Reserve is essentially for settlement and agriculture. There is, therefore, a high level of capitalization and asset ownership of agricultural implements. For instance, 56.8 per cent of the sampled settlers had ox-drawn ploughs, and 52.2 per cent had livestock (cattle, donkeys and goats). The settlers aim to produce a marketable surplus and to ensure a satisfactory level of food security at the household level. Data on asset ownership per gender is shown in table 3.

It was found that of the majority of the settlers, 70.5 per cent had opened small fields of < 5 ha each for the cultivation of maize, tomatoes, groundnuts, cotton, popcorn, sunflower and other crops. These fields are less than the land allocated to each settler, and therefore there is the possibility of further expansion after clearing more forest on the apportioned land. About 30 per cent of the settlers had opened fields of 10 to 11 ha each. However, there were some cases where enterprising individuals have opened up much larger fields. For instance, one Tonga headman (a retired soldier) with 30 children in his village, claimed that he had eleven fields covering about 400 ha and there was another 700 ha of land he has not yet cleared. Equipped with six ox-ploughs, a grinding mill and four donkeys, he was able to harvest 108 tonnes of maize in the 1996/1997 agricultural season, of which 83 per cent was sold. Sampled farmers harvested a total of 110.4 tonnes of maize in the 1997/98 agricultural season. Of this, men contributed 79.8 per cent while women only 20.2 per cent. In addition, men contributed 93.3 per cent and 71.5 per cent in terms of sales/exchange and food storage respectively. Women sold or exchanged only 6.7 per cent of their total production and stored for food only 28.5 per cent of total production. Women made a greater contribution, however, to the production of other crops like tomatoes, groundnuts and water melons which are sold.

As the process of opening up fields for agriculture takes place, some of the cut trees are converted to charcoal for fuel. About 23 per cent of the men and 14 per cent of women indicated that they produced charcoal. The sampled settlers sold nearly 28 tonnes of charcoal, of which 65 per cent was sold by women. Although two headmen emphatically stated that they discouraged their subjects from making charcoal as an economic activity, encouraging them instead to concentrate on agricultural production,

Table 3. Total assets owned per gender among sampled settlers in Muyama Forest Reserve.

Item	Men	per cent	Women	per cent	Total
Ox-drawn plough	32	78.0	9	22.0	41
Harrow	13	76.5	4	23.5	17
Ridger/cultivator	14	87.5	2	12.5	16
Scotch carts	14	87.5	2	12.5	16
Tractor	2	100.0	0	0.0	2
Tractor plough	3	100.0	0	0.0	3
Tractor trailer	1	100.0	0	0.0	1
Truck	1	100.0	0	0.0	1
Grinding mill	1	100.0	0	0.0	1
Hoes	78	45.0	95	55.0	173
Cattle (alive)	76	79.2	20	20.8	96
Cattle (killed by Corridor disease)	112	89.6	13	10.4	125
Goats	42	93.3	3	6.7	45
Donkeys	4	100.0	0	0.0	4
Pigs	3	100.0	0	0.0	3
Chickens/ducks	17	9.0	171	91.0	188

(Source: Field Data)

one could argue that it makes perfect economic sense for a settler to convert felled trees into charcoal as part of initial field clearance or annual extension in order to raise money for agricultural inputs, such as fertilizers. This is particularly true for resource-poor households.

The findings of the study suggest that encroachment into the Muyama Forest Reserve for settlement and agricultural production is quite serious, and has created a potential conflict between conservation of a forest on the one hand, and the need to meet land requirements on the other. Omosa (1998) argues that, in Kenya, most of the forested lands are situated in high potential agricultural areas and, as the rural populations increase, so do the pressures increase for converting forestlands to farms. Wily (1997) also argues that in many developing countries the strategy which traditionally has been followed in conserving natural forest resources by withdrawing them from the public domain into the hands of government, has been found wanting, given the increasing population pressure, hunger for land and demand for wood fuel and charcoal. This is so because 'the alienation of forests places government in direct conflict with traditional forest users, (while) the capacity of government to successfully 'guard' national forests is declining with retrenchment of staff, limited finances and lowered morale' (Wily, 1997, p. 69). The situation in Zambia is similar, especially with the implementation of the Public Service Reform Programme.

Mushove (1994) considers that encroachment on forest reserves, and other land categories set aside for uses other than human settlement and agriculture, is found as a solution by the so-called 'environmental refugees'. These include rural residents who depend on shifting cultivation and other related land uses for their livelihood. Thus, while the state makes a statutory claim to forest reserves and national parks, the environmental refugees try to exercise usufructuary rights over the land, trees and animals, and perceive forest reserves as 'land banks' or spare arable land.

Given the threat of human encroachment which forest reserves in Zambia and elsewhere face, and a situation of potential conflict between conservation and encroachment or illegal settlement, there is an emerging perspective which seems to suggest that this conflict could be peacefully resolved by involving individuals and local communities in managing the resources jointly with government through joint forest management (JFM).

Gakou and Force (1996) observed that 'a partnership between foresters and the people they serve is essential for the protection and long-term survival of both the people and the forest' (Gakou and Force, 1996, p. 19). Thus Tewari (1996) shows that the Government of India adopted a new forest policy in 1988, which addressed the social costs of excluding people from the local management of forest resources and introduced, in 1990, guidelines for involving people in the participatory/joint forest management programme.

In this programme legal ownership of land remains with the government or Forest Department, but village communities become co-managers in the management of forests. Communities are entitled to free usufruct benefits, a share of the timber and other major harvests from the forests. Both monetary and non-monetary benefits are enjoyed. Cash from the sale of timber and other marketable forest products such as bamboo is received, and non-economic benefits include those of ecological value such as improved soil; reduced runoff; increase in local biodiversity; the aesthetic beauty of the village landscape as well as the re-establishment of traditional leadership and the resolution of conflict through dialogue rather than confrontation. It could be argued that efforts to introduce this new concept and strategy are being advocated in Eastern Africa (Omosa, 1998), and in Southern Africa (McNamara, 1993).

In Zambia, the Government is refocusing forestry policy to ensure sustainable forest resource management. This new policy 'encourages the active involvement of local communities in the protection, management and utilization of forest resources' (GRZ, 1998, p 1).

The new policy, which departs from the approaches which have guided forestry development since independence in 1964, proposes to involve all the stakeholders – men, women, children, private investors, traditional leaders and local communities – in creating a partnership to ensure sustainable management of forest resources within the context of a liberalized market economy. It further aims at fostering partnerships between state agencies, local communities and individuals in the peaceful resolution of conflicts which may arise in the management and use of forest resources in a democratic state. The new principles also aim at promoting dialogue among key stakeholders and to enhance the sense of ownership of the forests by individuals and the local communities in line with the Land Act 1995, which makes provision for individuals to be empowered with title deeds to the traditional land which they cultivate (GRZ, 1998, pp. 2 to 8). In this regard Kapungwe (1997) considers that the most popular approach to conflict management which involves community-based natural resources management programmes, is the consensus approach. This involves, among other things, the re-empowering of local institutions, such as traditional leaders, or creating new ones to address new challenges.

However, Tewari (1996) raises certain pertinent issues with respect to the sustainability of the JFM institution or strategy. He raises issues concerning how the interest of the community can be sustained in participating in JFM and how the benefits can be shared between the community and the government, and acceptable methods of how members in the community should share the benefits amongst themselves.

During the village meeting with the settlers, the generative theme was that the Muyama Forest Reserve should be degazetted so that the people can live without fear of eviction by the state, may build permanent houses and schools for their children and engage in productive farming to ensure sustainable livelihoods. They saw this as the most suitable way of resolving the conflict since it was in line with the 'New Thinking' contained in the new joint forest management policy which was explained by the researchers. Settlers further indicated in individual interviews that they would welcome the granting of individual title deeds to the portions of land that had been granted to them so that they could enjoy greater security of tenure.

In attempting to resolve the apparent conflict, all the stakeholders will need to be guided by the spirit of the new government policy on the management of the forest estate and take into account the actual concrete situation on the ground in the Muyama Forest Reserve. We have noted that the settlers have full and effective occupation on the ground in their 20 villages, and the 'new spirit' is that government wants to work jointly with other stakeholders and empower its citizens with the means of leading sustainable livelihoods, through the use and sustainable management of available natural resources, in a liberalized economy. This includes the allocation of land to the landless rural communities and individuals for settlement and for food production. Therefore, there is a need to explore ways of achieving a meeting of minds between the demands of the settlers and the objective of empowering rural communities, individuals and their traditional institutions, as contained in the new JFM policy.

Conclusion

It has been shown that there is a serious problem of human encroachment into protected forest reserves in Zambia, resulting from pressures for more land for settlement and agriculture. This situation has created an atmosphere of conflict between conservation of forests and demands for settlement and agricultural land use. It has been further argued that in many developing countries, including Zambia, JFM policy is being refocused as a way of resolving the conflict situation and promoting sustainable management of forest resources by involving all the stakeholders in the management of forests.

In the case of the Muyama Forest Reserve, it has been shown that the settlers and/or squatters have full and effective occupation of the reserve, and there is a gradual but effective transformation of land use, from forest to agricultural land through settlement in homesteads. This has led to pressures from the settlers that the forest reserve be degazetted within the 'new spirit' of the JFM policy, as a way of resolving the apparent conflict situation.

It has been argued that the resolution of conflict should take into account the actual situation on the ground and consider the spirit of the new JFM policy which aims at empowering local communities, individuals and other stakeholders in the management of forest resources in a liberalized economy, to ensure sustainability of resource use.

Research implications and policy recommendations

It would seem that further research is needed to see how JFM policy will be implemented and assess the status of each forest reserve in order to work out modalities of effecting empowerment and resolving the apparent conflict situations, which may exist.

Acknowledgements

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Dryland Forest Conservation in South-West Madagascar

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Introduction

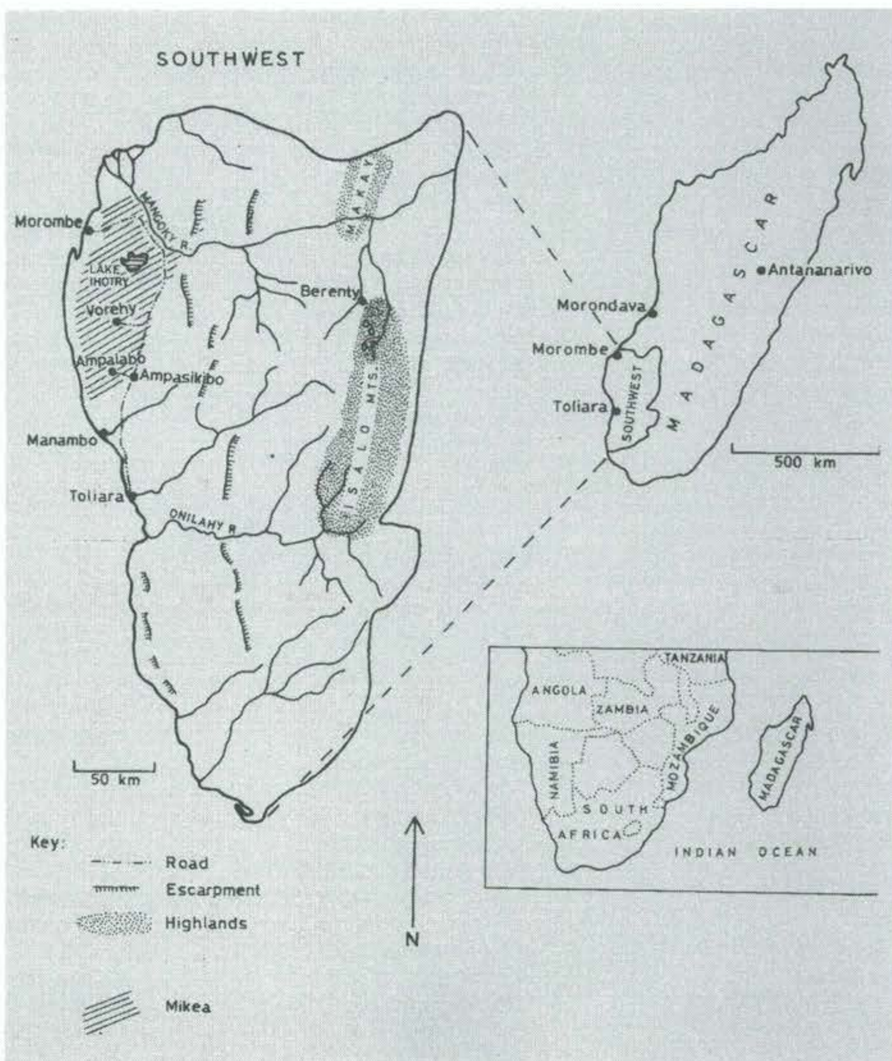
This article concerns an area of south-west Madagascar that comprises the Lake Ihotry/Morombe Ecological Complex and the Mangoky River Protected Area, both on the Madagascar Government's list of priority conservation areas. The forest area is inhabited full time only by the hunting-gathering group known as the Mikea (Stiles, 1991). The Mikea Forest, as it is known locally, contains hundreds of endemic plant and animal species. It is threatened by slash-and-burn agriculture and livestock grazing. Knowledge of natural resource use by the local population is critical to formulating a workable conservation management plan, to which this article contributes.

Location and environment

The Mikea are a little known group of between 1,000 and 2,000 people who live in the semi-arid Mikea Forest of south-western Madagascar (figure 1). The agro-pastoral Masikoro and Antandroy live to the east and the fishing Vezo people live along the coast to the west. The Mikea live on the eastern edge and in open pockets of a dry forest between Morombe and the Mangoky River in the north and the town of Manambo in the south, an area of about 2,000 km^2. The Route National 9 runs north-south to the east of Mikea country through a relatively well-watered (800 mm mean annual rainfall) and fertile valley occupied mainly by the agro-pastoral Masikoro people. This dirt road is the main communication with the outside world. The main Mikea occupation area receives less than 600 mm of rainfall a year, declining to 400 mm near the coast.

The soil is mainly sand, covered by a surprisingly dense and rich tropophitic forest in the east grading into a xerophytic spiny forest nearer the coast. Over 60 per cent of the plant families are endemic to Madagascar, as are 90 per cent of the species (Hoemer, 1986).

Appendix I provides a list of what I have been able to gather concerning the indigenous and botanical plant names.



Appendix I Mikea Plant List

Mikea Name	Botanical Name	Uses
(h)afi(,h)afv	*Avicennia marina*	Mangrove, timber for houses make mortars (*leo*); firewood; sap (*loko*) used as antiseptic and for toothaches.
ahidambo	*Heteropogon contortus*	Grass, house walls and roofs.
akao	*Casuarina equisetifolia*	Boat masts.
amaminomby	*Terminalia boivini*	Cart yokes and tool handles.
amiana	*Urera radula*	Water in root; bark rope.
anatsiko	*Securinega syrigii*	Poles.
andrarezana	*Celtis madagascariensis*	Bark, treat gum disease
angily	*Diascorea sp.*	Edible tuber.
antake,	*Psophocarpus longipendunculabus (?)*	Smelly vine with edible seeds that are boiled and can be sold.
antaly	*Dioscorea antaly*	Edible tuber.
antso	*Euphorbia antso*	Sap used as poison; in past used to start fire by friction.
arofy	*Commiphora guillamini/ mafaidoha*	Bark used to treat wounds.
ba	*Ipomea sp.*	Large tuber with much water.
babaka	*Curcurbitaceae (?)*	Squash, make containers; (Hoerner, 1986:21 mentions a grass by the same name: Sorghum alepensa).
babo	*Dioscorea bemandy*	Water source in dry season.
bakakely	*Tribulus terrestris*	Herb with spicy seeds.
banakipaky	*Bauhinia grandidieri*	?
bararata	*Phragmites communis*	Reed.
bevory	?	Vine, soap made from roots.
bokaby	?	Vine, latex from fruit sold.
borovy/dray	*Strychnos spinosa*	Edible fruit.
boy'	*Physena sessiflora*	Planks in construction; wooden cylinders. used in iron piston bellows.
famata	*Euphorbia stenoclada*	Masikoro use sap (loko) to stun fish.
famehifary	*Clitoria lasciva* (?)	Vine, sap a purgative.
famoahalambo	*Dichrostachys* sp.	?
fanamba	*Cadia elisiana* (?)	Bark, grind into fish poison.
fantsiholotse	*Allaudia procera*	Similar to sono, no uses (not local).
fantsiholitra		
fandsihotse	*Mimosoideae*	Bark cordage for nets.
fany	*Entada chrysostachys*	Seeds used in divination (sikily.
farafake/	*Givotia*	Boat construction; bark used by women to farafatse madagascariensis make skin cream masks (babaky).
fegoky	*Delonix bioviniana*	Wood too spongy to work.
fiamy	*Ficus sp.*	Attracts sifakas.
fony	*Adansonia fony*	Bark, makes cordage (haftse or hafuke) and roofing; fruits eaten and made into juice; seed pods used as scoops; wood boiled and drunk to treat fevers and colds; sacred tree faly) in which spirits (koko) live.
giradivahiny	*Fleminga congesta*	?
hafihany	*Avicennia sp.*	?
halimboro	*Albizia bernieri*	?
hamafana	*Cissampelos pareira*	Vine.
handy	*Neobeguea mahafaliensis*	Timber, construction; boil bark in water to strengthen post-natal mothers, wash infants, and treat backaches.
harahara	*Phyloxylon ensifolius*	Construction.
hatafa	*Terminalia catappa*	Tool handles.
hazo mafintio	*Stadmania oppositifolia*	Boat construction.

Appendix I Mikea Plant List (*Contd.*)

Mikea Name	Botanical Name	Uses
hazo mafio	?	Treat gonorrhoea.
hazo malany	*Hernandia voyroni*	Planks for carts, floors, doors and coffins; leaves and barks used to treat jaundice and infected sores.
hazo manitse	?	Edible seeds.
hazo mbalala	*Croton mahafaliensis*	No uses.
hazomby	*Strychnos madagascariensis*	House construction; roots an anti-inflammatory.
hazo tsakorova	*Grewia sp.*	Boil leaves and drink for malaria.
hola	*Dracoena reflexa*	No uses.
intisy	*Euphorbia fiherensis*	Sap used as caulking.
kapaiko	*Nelumbo nucifera* (?)	Lotus, boil tuber food.
katra/kata	*Cesalpinia dunducella*	Seeds used in board game.
katrafay/katrasafa	*Cedrelopsis grevei*	House construction; digging sticks; bark and leaves used to treat many problems – rheumatism, backache, diabetes or to reinvigorate; bark used in toaka gasy.
katramantse	?	Bark, house walls and roofing.
kidresv	*Cynodon dactylon*	Weed that harms cultivation.
kily	*Tamarindus indica*	Some are sacred (hazo faly); sell fruit pods.
kinany	*Ricinus communis*	Ombiasy keeps oil in cow horn and uses in charms.
kirondro	*Perriera madagascariensis*	Fruits highly toxic.
kiseny	*Cucumis melo*	Gourd.
komokomoky	*Grewia grevei*	Poles, tool handles; edible fruit.
lalanda	*Ipomoea pescaprae*	Edible tuber.
lamoty	*Flacourtia indica/ramoutchi*	Boat caulking; edible fruit, toaka gasy; bark is an antirheumatic.
laro	*Euphorbia laro/ Leucodendron sp*	Sap as fish poison.
latabarika	*Grewia cyclea*	Tool handles.
laza	*Cyphostemma laza*	Vine.
lombiri	*Cryptostegia madagascariensis*	Extract rubber (pira); 'cotton' from fruit used for blowgun dart fleches.
lopingo	*Diospyros platycalix*	Black (ebony), make sagia shafts.
maintifototse	*Diospyros sp.*	Leaves pounded and boiled as diarrhoea medicine for children, root is an anti-inflammatory, and bark is used as toothpaste.
mainte-mpo	*Indigofera depauperata*	Boat construction.
makamby	*Nmphaea stellata* (?)	Waterlily root, edible.
mampandry	*Cedrelopsis gracilis*	Poles in construction; bark infusion to treat fever.
manary baomby	*Dalbergia greveana*	Construction, firewood; pieces of branches cut to use for medicinal purposes (volo hazo), rubbed on stones with water to produce a paste which is applied to the face (tabaky) for numerous purposes; sacred tree for Mikea –Vezo.
manary fotse	*Dalbergia purpurescens*	Construction.
manary tsiatondro	*Dalbergia trichocarpa*	Contruction, house poles.
mandrofo	*Trachyloblum verrucosum*	Gum copal (not in area).
mangarahara/ mangerahane	*Stereospernum rufus/ euphoroides*	Boil bark to treat diarrhoea; wood for coffins.
mangiliakeliky	*Brachylaena microphyilla*	No uses.
manjakabenitany	*Baudoulnia fluggeiformis*	Sacred tree.

Appendix I Mikea Plant List (*Contd.*)

Mikea Name	Botanical Name	Uses
mantaora	*Cedrolepsis microfoliolata*	Firewood and poles.
maro sarana	*Moringa drouhardii*	No uses.
mita	*Cyperus articulatus* (?)	Reed, baskets and mats.
moky	*Ipomoea* sp.	Edible small tuber.
monongo	*Zanthoxylum tsihanimposa*	Cart construction; bark infusion to treat fever.
nato	*Sideroxylon sp/ Capurodendron perrieri*	Timber for coffins; fruits not eaten; bark used for red-brown dve used on cloths (lamba).
nonoke	*Ficus megapoda/melleri*	Bark cloth (in past); holds water in cavities; boiled leaves treat many illnesses.
ovotra	*Typha augustifolia*	Reed.
ovy	*Dioscorea ovinala*	Edible tuber.
rafia	*Sagus rofia*	Raffia palm. basketry, mats, etc.
raketa	*Opuntia dillenii/inermis*	Cactus, eat, prickly pear; cattle forage. ravinengitra/Landolphis Vine, extract rubber.
fingitry	*madagascariensis* (?)	
renala	*Adansonia grandidieri*	Bark. cordage, edible fruit.
robotsy	*Acacia morandaviensis*	Firewood.
roitra/roy	*Acacia asperata*	Firewood.
rombe	*Commiphora* sp.	Fragrant leaves and flowers; boil and inhale vapours for colds.
sakoa	*Poupartia sylvatica/ caffra*	Wood; make mortars; edible fruit; fire resistant.
sambalahy	*Albizia perrieri*	Bark used to treat asthma and leaf infusion for stomach ache and fever.
saonjo	*Colocasia* sp.	Taro, edible tuber.
sarongaza	*Colvillea racemosa*	Beautiful red-orange flowers.
sasavy	*Salvadora augustifolia*	Fruit; treat toothache with ground root.
satsa'satrana	*Hyphaene shatan/ Medemia nobilis*	Basketry; fruit (lakoko), toaka gasy house thatch.
sono	*Didiera madagascariensis*	No uses.
somotsoy	*Fernandoa madagascariensis*	Colonizes deforested areas; leaves in infusion to treat fever, ground up to treat diarrhoea.
songery,	?	Mangrove.
sono	*Allaudia ascendens*	Remove spines and use for house poles.
sosa	*Dioscorea sosa*	Edible tuber.
talafotsy	*Rhopalocarpus lucidus*	Tool handles; bark cordage.
talamena	*Apaloxylon tuberosum*	Bark cloth in old days.
taly	*Terminalia tricristata*	No uses.
tanga lahi	*Rhizophora mucronata*	Mangrove, tannin for trade.
tanga vave	*Ceriops tagal*	Mangrove, boat masts.
tapia	*Uapaca bojeri*	Fire resistant tree; leaves feed silk worms.
tavolo	*Tacca pinnatifida*	Arrow root. grind up and put in cloth, pour water over it, use starch precipitate in water as food.
tongarivomena	*Sesbania rostrata*	No uses.
tsanaoday	*Robetelia* sp.	Giant grass, no uses.
tsiakondrokondro	*Angraecum superbum* (?)	Orchid.
tsiana	*Sporobulus indicus* (?)	Grass, fodder.
tsilaiby	*Stadmania oppositifolia*	Fire resistant.
tsinefo	*Zizyphus vulgaris*	Jujube fruits and toaka gasy.
tsingilofilo	*Calastrus linearis*	House and boat construction.
tsitake	*Rhus perrieri*	Resin used by girls as a depilatory, and by ombiasy in rituals.
vahe mainte	*Secamonopsis* sp.	Rubber vine; latex strong enough to patch tyres.
vahintana	*Albizia masikororum*	Construction, firewood.

Appendix I Mikea Plant List (*Contd.*)

Mikea Name	Botanical Name	Uses
vaho	*Aloe vahombe*	Treat skin lesions with raw juice; boil leaves and drink for yellow fever.
vakakoa	*Strychnos vacacoua*	Medicine to treat leprosy.
valotsy	*Breonia perrieri*	Found in humid depressions; wood can be worked.
vaovy	*Tertrapterocarpon geayi*	Cart frames and wheels; boats; boil bark and drink as an anti-malarial.
varo	*Cordia* sp./ *Hibiscus liliaceas* (?)	Boat construction.
vero	*Hyparrhenia rufa*	Tall grass around water depressions.
voa manga	*Citrullus panatus*	Gourd.
voandry	*Ficus* sp.	No uses.
vondrol/vondzo	*Typha augustifolia*	Reeds, house construction.
voro	*Alleanthus greveanua*	
vontaky	*Pachypodium geayi*	Soak sapwood in water as bush pig poison; bark cloth.
vory	*Alleanthus greveanus*	Construction.
za	*Adansonia za*	Bark used as cordage; fruits eaten; pods used as scoops.
zaha/hazo foty	*Grewia microcyclea*	Shaft (*voloso*) for spear used in pig hunting and tool handles; roofing; edible fruit; bark string.
zavy	*Ficus* sp.	No uses.

Note: Toaka gasy is a home-made alcoholic brew.

Animals consist of a number of species of small hedgehog-like creatures generically termed tenrec, lemurs, viverrid carnivores (similar to civets), and the African bush pig. All of these animals, except the pig, are found nowhere else but Madagascar. There is a great number of birds, many species endemic, along with the African Guineafowl. Appendix 2 presents a faunal list with uses. As recognition of this important area of biodiversity, the northern part of the forest, including the saline Lake Ihotry, has been designated a protected ecological complex by the government. The area is under threat. A type of degraded secondary bush, called *hatvake-moka*, is expanding due to slash-and-burn agriculture.

The sandy soil and lack of perennial streams (except the Mangoky River) result in most of Mikea country being totally devoid of water during the latter half of the dry season, about late June to late November. During the rains, December to April, Mikea find water in pools (vovo) and in tree hollows. The coolest, driest months are June to September. The poor soils and lack of water offer the Mikea *some protection from invasion by neighbours, though cattle grazing by Masikoro and Antandroy is increasing in the area, putting more pressure on the fragile ecosystem.*

Subsistence and settlement patterns

The Mikea have a well-developed system, with a structured annual cycle. The Mikea distinguish three internal social subdivisions, and in general they display different ways of living and types of settlements: the Mikea-Masikoro, the Mikea-Vezo and the 'true' Mikea. Because of trade and intermarriage there is a certain amount of mixing, but I will present an idealized version of the 'average' Mikea.

There are five types of house in which a Mikea could be found: the trano, a semi-permanent, rectangular wattle-and-daub thatched structure common to the Masikoro (though it can sometimes be made of wooden planks) found in agricultural villages; the tsano, a flimsy hut made from reeds, palm leaves and/or mats always located on the beach or coastal dunes; the tongalibaty, a ~1.5 metre high, small rectangular hut made of bark, usually of the baobab tree; the vohitse, a small rectangular hut made entirely of *ahidambo* grass (*Heteropogon contortus*); and finally, the tsangatsanga, a lean-to open at either end usually made of bark, though it could be of grass. These house types are related to settlement type and subsistence pursuit.

Seasonal cycle

The Mikea year begins in about October, when thunder sounds the approach of the rainy season (fig 2). This month and the next is called faova, it is hot and relatively humid, with occasional scattered rain showers near the end. The forest Mikea are living in the deep forest now, sleeping outdoors under trees or in hollowed-out termite mounds, doing what they call kizo. They are living entirely from hunting and gathering, and the prime purpose is to collect as many edible tubers as possible, which they stockpile. The main tubers are wild yams (*Diascorea* sp.) which they call *ovy, sosa, babo*, etc., the *ba, moki* and *lalanda* (*Ipomoea* sp.), *saonjo* (olocasia

Appendix 2	**Fauna**	
akanga	*Numida mitrata*	Guineafowl, meat.
akohoala	*Lophotibis cristata*	Crested wood ibis, meat.
amboalava	*Chamaeleo* sp.	Chameleon.
angavo	*Pteropus* sp.	Fruit bat meat.
aomby	*Bos madagascariensis*	Cow, almost never owned by Mikea; in past 'Hattoy's cattle' feral and hunted.
bengy	*Capra capra*	Goat, used mostly in ritual.
boenga	?	Large rodent (?), meat.
boky-boky	*Mungotictus decemlineata*	Viverrid, meat.
fosa	*Cryptoprocta ferox*	Largest carnivore in Madagascar, similar to civet, meat.
gidro	*Lemur fulvus*	Brown lemur. Meat.
hira	*Lemur catta*	Ring-tailed lemur, meat.
kapiky	*Pyxis planicauda*	Turtle, meat.
katrakatraka	*Eremialector personatus*	Sandgrouse, meat.
kibodolo	*Turnix nigricolis*	Small quail, meat.
kituky	?	Bee, wild honey.
kivahy	*Canis canis*	Dog, used in pig and fosa hunts.
lea; reny tantely	*Apis unicolor*	Honey bee, 'mother of honey'.
mangoro lambo	*Potamochoerus larvatus*	Bush pig, meat.
moky	*Anopheles* sp.	Mosquito.
ongiky	*Cheirogaleus medius* (?)	Dwarf lemur (?) meat.
rere	*Erymnochelys madagascariensis*	Sideneck turtle, food and offerings.
sakondry	*Fulgoridae*	Edible insect.
samaky	*Phoenicopterus* sp.	Flamingo, meat.
sifaka	*Propithecus verreauxi*	Lemur, meat.
sora	*Hemicentetes semispinosus*	Small banded tenrec, meat.
sotrosono	*Platelea alba*	African spoonbill, meat.
tambotsike	*Echinops telfairi*	Tenrec, meat.
tandray	*Centetes ecaudatus*	Common tenrec, meat.
tsangafiafy	?	Caterpillar, can burn skin.
tsingaokaoke	*Hippobosca maculata* (?)	Tiny fly that is numerous in dry season in forest and sucks blood.
valavo	*Rattus rattus*	Rat, meat.
vivihy	*Dendrocygna viduata*	Whistling duck, meat.
vorombengy,	*Threskiornis aethiopicus*	Sacred ibis, meat.
vositsy	*Hypogemus antimena*	Jumping rat, meat.

Month	Season	Climate	Subsistence	Settlement
October, November	Foasa	Hot, humid	Collecting tubers, pig hunting, burning fields	Kizo
December, January, February, March	Litsake	Rain	Planting, hunting, tenrec, honey, dried tubers maize harvest	Tana (Vohitse)
April, May, June	*Limberano/*	*Transition* (Tongalibaty)	*Maize, tubers, tenrec*	*Tana Ferarano*
July, August, September	Asotry	Cool, dry	Clear fields, hunt lemur, birds, dry and stockpile tubers	Kizo

Fig. 2: The Mikea annual cycle

Photo 1. *A Mikea hunter-gatherer carries home the day's wild yams in a net bag.*

sp.), *tavolo* (*Tacca pinnatifida*) and others. They dry the tubers they don't eat and in November make several trips to transport them to the band semi-permanent village, called tana. Tubers are carried in bark cordage net bags called *koko*. Bush pig (55 to 80 kg) and lemurs are the main animals hunted during this period, as the tenrec species are aestivating in holes in the ground and in tree hollows. The pig hunts, with spears and usually dogs, are called *mangoro lambo*. Sometimes pits are dug (*pongy*) to catch them. Lemurs and birds are usually killed with a blowpipe (*porotsy*), sometimes a sling (*pira*) and birds sometimes trapped in *afitseboke*. The Mikea no longer use bows and arrows for hunting, though children play with them, shooting insects and birds.

The rainy season, December to late March or early April, is called *litsake*. The *tana* are located in a clearing in the forest, and the fields to be cultivated are usually in the vicinity. The forest was cleared before going into *kizo* and the dry matter is burned off at the first signs of rain. In December, with the first rains, maize and sometimes other crops, such as cassava, are planted. The slash-and-burn system is called *hatvake*. The fields are small and not really looked after; there will be from one to two weedings during the whole growing period. The people hunt mainly tenrec during this period, as they come out of aestivation, and eat the dried tubers gathered during *kizo*, as those in the ground are growing and are not good to eat until near the end of the rains in late March. When Mikea dig out tubers, they usually leave a piece in the ground (*amparahaly*) to regenerate. Tenrec, slow-moving creatures, are usually killed with a throwing stick or club. *Litsake* is also a main honey collecting period. In April the maize is harvested. The best ears are kept to eat and as seed, and the rest is sold. The tana marks the central area of a band's territory, and the village itself shifts around within it in response to availability of tubers. During the rainy season most Mikea live in *vohitse*.

Late April to June is a transitional period, called *limberano* by the Mikea-Masikoro and fararano by the Mikea-Vezo. People eat the maize harvest in these months, and continue to forage. Many bands move away from the fields deeper into the forest and tuber sources, and build or re-use the tongalibaty. In June water starts to be a problem. From July to November the sole source of water for many Mikea is the *babo*, a tuber. Other tubers are even cooked in its water. Large tubers can give a litre or more of water. The more sedentary period, December through June, in the camps is called *antaniney*, from *tana*.

The size of these camps can vary widely. The true forest Mikea, who have little to do with the Masikoro villages, live in simple settlements of from two to

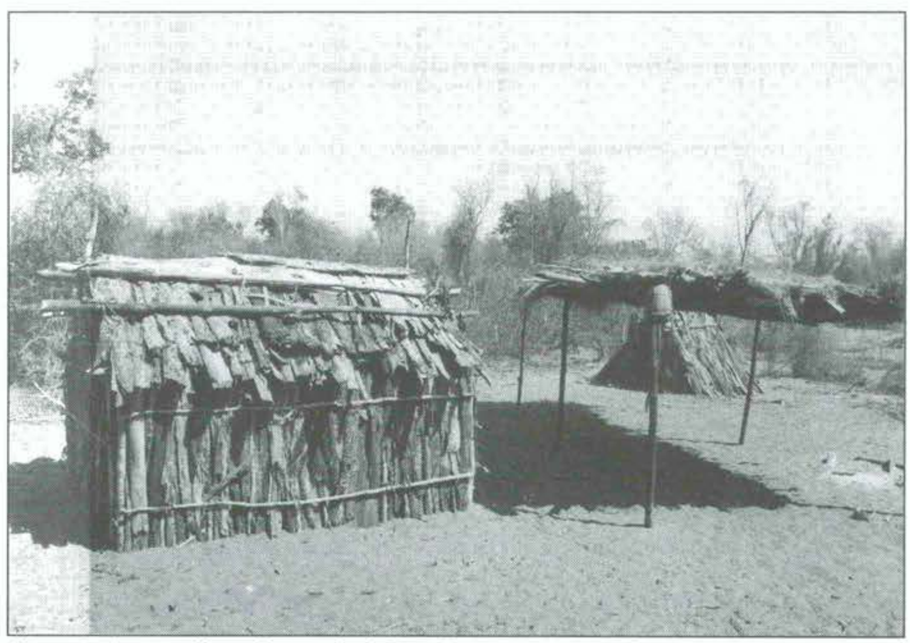


Photo 2. *A tongalibaty hut to the left and a tsangatsanga lean-to to the right in the background, both made from tree bark.*

six huts and 10 to 25 people, including children. Andranohazo-Betampy, one of the bands I studied, is such a type. Another I worked with, who were Mikea-Masikoro, called Benofy, was larger. It had eight large *tongalibaty and perhaps* 40 people. They had left the forest a few years previously to move to Vorehy, a village with a European missionary, health clinic, permanent well and market. But they survived poorly trying to cultivate, so they had returned to the forest and hunting-gathering, which provides a more reliable and varied food supply and, in addition, forest trade products. But they had brought metal water drums, an ox-cart, two oxen and four goats with them. They had also set up an iron-working forge, and made their own digging spades, knives, etc. from scrap metal. Other Mikea-Masikoro camps, such as Bedo, were even larger.

Late June through September is called asotry, the cool, dry season. In June and early July many bands spend time cutting the forest in preparation for the rains. Others wait until October or November. The determining factor is the time they plan to spend in *kizo*. Most bands leave tana and go into *kizo* in late June or July. The tenrec go into aestivation now, but life is similar to that of faosa. The tenrec holes are cleverly dug, with many twists and changes of direction so that they cannot be found, though every once in a while a Mikea can spot the breathing hole and will dig the poor creature out. Each band has a distinct, named *kizo* territory that is unoccupied for the rest of the year. It has to contain a good quantity of babo, as this is the only source of water, except in the Namonty area where there are more permanent ponds from phreatic waters. Fishing is even done in this area.

The Mikea-Mezo on the coast and Mikea-Masikoro living in larger mixed villages do not normally go on kizo for more than a few days at a time, for a specific purpose – to find a tree for making a boat, to collect honey, medicinal herbs, or a few tubers to fill a shortage. The Mikea-Vezo do not make forest camps, and spend the majority of their time fishing and collecting sea produce. They, along with the Vezo proper, carry out a type of foraging on the reefs at low tide, called *mihake*. The asotry season is particularly important for this, and the people move camps often along the beach. Some move to offshore islands, living under their sails as tents, and specialize in collecting and drying trepang (sea slugs) for export to the Far East.

There is, therefore, a great range in subsistence pursuits and settlement patterns with the Mikea. I was told that south of the Namonty area there were even one of two groups that were in *kizo* all year, i.e. complete subsistence living. At the other end of the spectrum there are Mikea who are full time agriculturalists living in *trano* and villages like the Masikoro. Individuals and groups, such as Benofy, also change their emphasis on how they will make a living in response to what seems the better deal. In short, most Mikea are opportunists, a common theme among foraging peoples anywhere.

Trade

Trade is very important for the Mikea, but not for subsistence. The most important thing men want is tobacco snuff (*paraky*). They cannot live without it and will go into sirize, a nicotine fit, if they cannot get it. Other sought-after items are metal tools, cloth or clothes, rice, salt, and rum (needed for religious ceremonies). In return, they trade honey, tubers and meat (mainly tenrec and lemurs). In the past, silk cocoons (*koohok* and *landi*) and wild rubber (*pira*) were important. The forest Mikea mainly trade with Mikea-Masikoro or Mikea-Vezo, as they dislike outsiders; the Mikea-Masikoro will trade with Masikoro and other tribes living in the villages on the R.N. 9. This small trade, often barter, is called kinanga.

The people of Benofy use their ox-cart to haul tubers to Vorehy. I was told that one man could fill a cart with tubers in only six hours of digging. Some of the tubers are traded for cassava, suggesting the trade is more for social than for subsistence reasons. Honey is the most important trade item, however, and the Mikea construct simple hives (*tohoke*) from hollowed-out logs which they leave on the ground. They are individually owned, as is the honey.

The Mikea-Vezo have a wide range of sea products they trade with Indian merchants (*Karani*) or their agents (*duka*). These include various fish, sea food (lobster, crab, prawns), trepang (to Hong Kong), mother-of-pearl, and an incense (fimpy) taken from the opercule of the mollusc *Murex trunculus* that the Karani particularly value. Salted fish and octopus are traded with the Masikoro for cassava

Photo 3. *Wild forest products already have a market in Madagascar, as here in the regional capital of Tulear, but the market could be expanded to provide income for the Mike*

or maize. The Mikea-Vezo differ from the Vezo in that the latter do not exploit forest products. It is the Mikea who procure all of the different kinds of woods, cordage and caulking materials from the forest for the construction of the Vezo outrigger boats, and some Mikea are expert boat builders (Koechlin, 1975).

The young, unmarried men do much of the transporting of the trade items, and they frequently move around from camp to camp and to the villages. They are also looking for a prospective bride. They call this moving around tsangatsanga, which gives the name to the lean-to, which is what they usually sleep in.

Discussion

The hatvake system of agriculture is threatening the forest. The principle crops of maize and cassava are needed to supplement wild food resources, particularly during the *limberano* transitional season, and the maize is an avenue to other goods through trade. It would not be feasible to forbid agriculture completely to conserve the forest, unless an alternative could be provided. The lists of the flora and fauna provided here and their current uses suggest at least one approach. Two solutions seem possible:

1. Develop trade in wild forest products and crafts and services based on them to provide adequate income with which to buy supplemental food and necessary goods. There may be markets for wild rubber, silk cocoons, aromatics, medicines, cosmetics and so on;
2. Identify inexpensive, practical fertilizers that the Mikea could use that would allow them to re-use cleared fields over extended periods, reducing the need to clear and burn additional forest. A system of field rotation, consistent with land tenure customs, should be included.

Sustainable offtake of renewable forest products and well managed shifting cultivation should be able to provide for both an improved subsistence economy for the Mikea and the conservation of the Mikea Forest biodiversity.

Because of the lack of water, seasonal grazing by livestock does not appear at present to be a serious problem, though any plans for water development, for example boreholes, should be discouraged in the vicinity of the protected areas.

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News from UNEP

The Third International Training Course on the Antropogenic Degradation of Landscapes and Ecological Security for the Commonwealth of Independent States (CIS)

Photo 2. *Participants observe Land degradation caused by gully erosion in Volgograd Region.*
Photo: L. Kroumkatchev, UNEP.

The Third International Training Course on the Antropogenic Degradation of Landscapes and Ecological Security for the Commonwealth of Independent States (CIS) was held in Volgograd, Russia from 6 to 26 September 1999. It was organized by UNEP in co-operation with the Centre for International Projects (CIP) and the All-Russia Scientific Research Institute of Agroforestry Amelioration (VNIALMI).

The overall objective of the training course was to address the issues of desertification/land degradation in arid and semi-arid ecosystems with a special focus on:

- Facilitating the extensive use of the application of proper methods of conservation, reclamation and management of lands in arid zones;
- Promoting development of internationally acceptable method-ologies and techniques for desertification control;
- Strengthening regional and international cooperation in anti-desertification activities;
- Improving the capacity of countries concerned in the CIS region to deal with desertification issues through exchange of information, experience and training.

In all, 40 participants from twelve CIS countries (Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, the Russian Federation, Tajikistan, Turkmenistan, Uzbekistan and Ukraine) attended the course which was both practical and theoretical and incorporated lectures, seminars, discussions, the exchange of

Photo 1. *The Third International Training Course in Volgograd, VNIALMI.*
Photo: L. Kroumkatchev, UNEP.

national experiences, field studies and study tours.

About 30 prominent scholars and experts from leading research institutions and universities from the Russian Federation were invited to share their knowledge and experience. More than thirty reports were presented by participants on the major desertification/ land degradation problems in their republics.

On completion of the training programme, an evaluation meeting was organized and all trainees were presented with certificates.

National Action Programme (NAP) in the Republic of Armenia

Armenia is a landlocked and mountainous country with small territory, high population density, fragmented relief ranging in altitude from 380 to 4,095 metres above sea level. The territory of Armenia is 29,800 km^2, the population 3.5 m. Of Armenia's territory, settlement areas occupy 4.6 per cent, industrial facilities 5.5 per cent, forests 14.9 per cent, reservations 2.9 per cent, national parks 5 per cent. For each inhabitant of Armenia there is 0.8 ha of land and 0.13 ha of forest.

In the southern plain regions the climate is arid and extremely continental; in the northern mountainous regions it is milder and damper. One-sixth of the country's territory is occupied by the watershed of Lake Sevan, one of the biggest freshwater mountain lakes. The location of Armenia on the cross-way of three bio-geographical zones prescribed a rich composition of flora and fauna.

The struggle against considerable water and wind erosion of lands, mudflows and landslides due to the mountainous relief of Armenia is a serious undertaking; human factors also have negative influences on land status. Of the total 1,400,000 ha of the agricultural areas, 830,000 ha are eroded, whereas only 3,900 ha are recultivated. The area of lands subject to salination amounts to 40,000 ha. Soils are polluted by heavy metal ions, introduced by irrigation of inadequately treated wastewater and industrial drainage.

The United Nations Convention to Combat Desertification (CCD) is to be implemented through National Action Programmes supplemented by regional and sub-regional one programmes. Effective action to combat desertification must be carried out locally and be adapted to local circumstances and conditions. But action must also be integrated with national and regional strategies, to ensure that it gets adequate priority, that duplication is avoided and that resources are used to the best advantage.

National Action Programmes form the very core of the treaty. They identify the factors contributing to desertification, and propose practical measures necessary to combat it and to mitigate the effects of drought. They should also specify the respective roles of government, local communities and land users and what resources are needed, and which are available.

Within the CCD and UNEP 1999 work programme, the Land Unit assisted the Government of the Republic of Armenia to elaborate the National Action Programme to Combat Desertification (NAPCD). The Ministry of Nature Protection undertakes the action programme in Armenia with financial and technical assistance from UNEP. In August 1999 the Ministry of Nature Protection organized a one-day meeting. At the meeting a deep analysis of the factors contributing to desertification was made, together with practical measures necessary to resolve desertification problems in the country. As an outcome of the meeting, the outlines of NAP were discussed and drafted. A working group on NAP development, and a co-ordinating team, were established consisting of leading scientists, experts from different ministries, agencies and non governmental organizations (NGOs).

Sub-regional Action Programme to Combat Desertification for the South-Eastern European part of the Russian Federation

In accordance with the United Nations Environment Programme corporate programme framework, 1998 to 1999, the sub-regional National Action Programme (NAP) to combat desertification for the south-eastern European part of the Russian Federation, was developed by the All-Russian Scientific Research Institute of Agroforestry Reclamation (VNILMI) in co-operation with leading scientists and experts from scientific research institutes of the Volga region, non-governmental organizations (NGOs) and with financial and technical assistance from UNEP. The total area of the sub-region is 438.700 km^2. The sub-region NAP includes the Dagestan, Kalmykia and Tatarstan republics and the Astrakhan, Samara, Saratov and Volgograd regions.

The sub-region programme includes a deep analysis of the causes of desertification as well as an action strategy involving the monitoring of desertification processes, environmental zoning of the republic, improvement of pastures and hay lands, reduction of the social and economic consequences of desertification and other issues relating to the resolution of the desertification problem.

National Forum on the Process to Combat Desertification and Drought in Uzbekistan

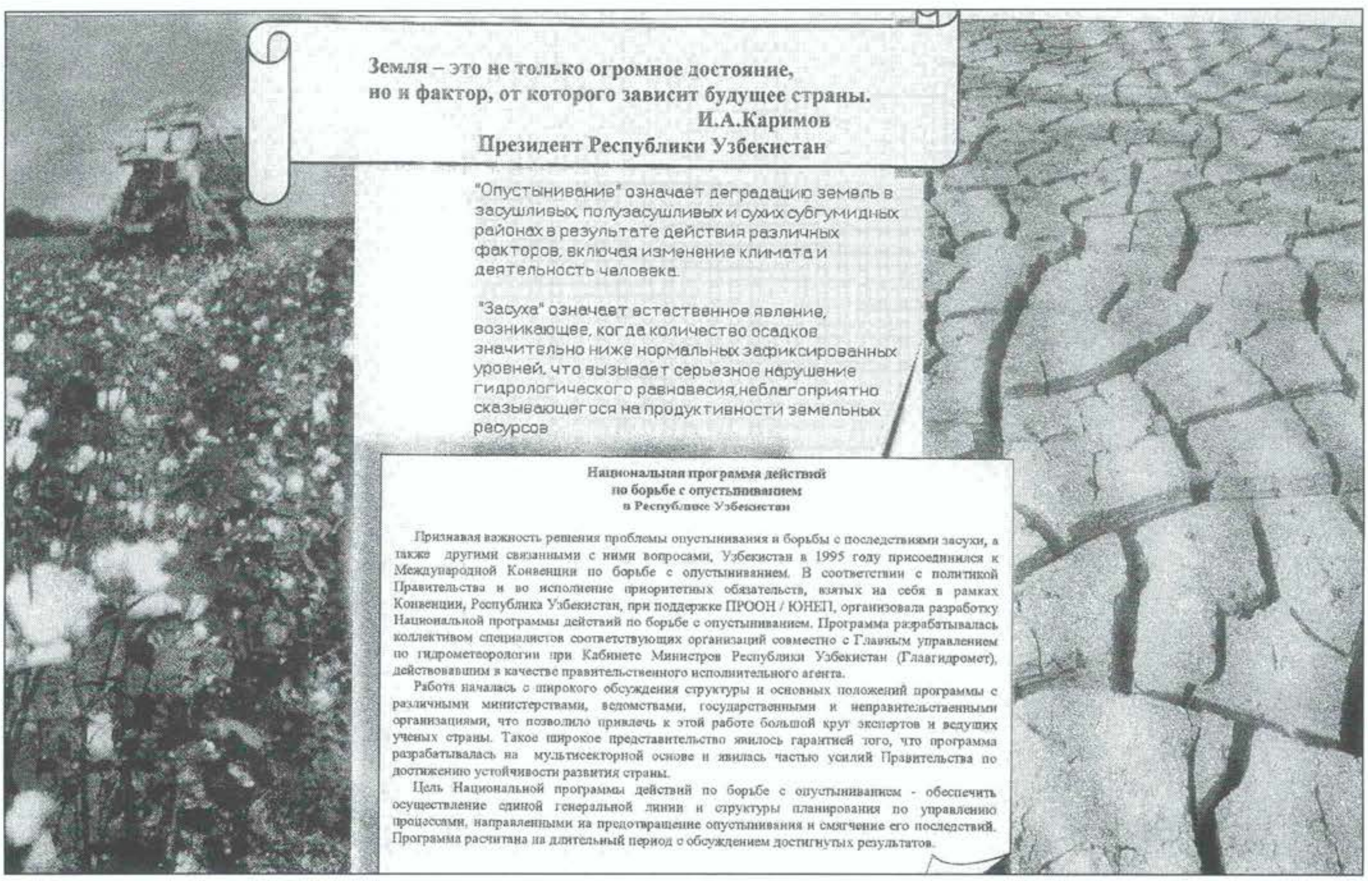
The National Action Programme (NAP) to combat desertification in the Republic of Uzbekistan was developed by the main administration of Hydrometeorology (Glavgidromet) in cooperation with leading scientists, experts from different ministries, agencies and non governmental organizations (NGOs) of the country with financial and technical support from the United Nations Environment Programme (UNEP) in accordance with new approaches of the United Nations Convention to Combat Desertification in Those countries Experiencing Serious Drought and/or Desertification, particularly in Africa (CCD).

Within the republic's programme on NAP development a national forum on combating desertification and drought was organized by Glavgidromet in co-operation with UNEP, United Nations Development Programme, (UNDP), United Nations Sudano-Sahelian Office (UNSO) and CCD Secretariat in Tashkent from 6 to 7 July 1999.

The aims of the national forum were:

- To identify priority programme elements within NAP, approaches and co-ordinating mechanisms for NAP implementation;
- To exchange information on programme activities in the country in support of NAP and CCD implementation;
- To discuss financial mechanisms among government agencies, NGOs and United Nations agencies in support of the NAP;
- To identify practical arrangements or harmonization of various agency activities and to develop a common operational approach and inter-agency strategy to support the NAP.

The national forum adopted resolutions on NAP implementation in the Republic of Uzbekistan.



Book reviews

The New Comprehensive Guide for Afforestation and Tree Planting Practices

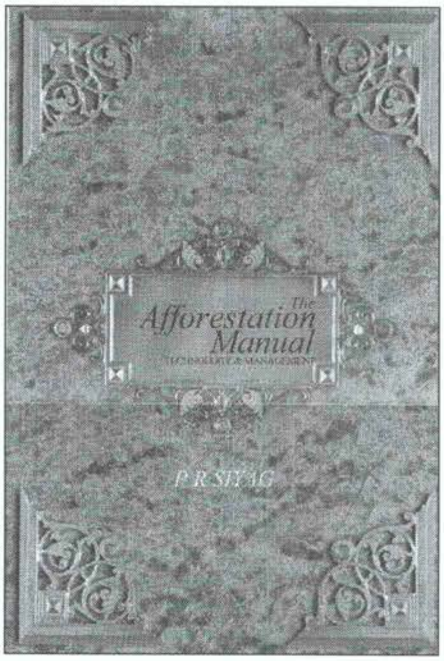
This pathbreaking work is a manual of practice for executing afforestation and tree planting programmes in arid and semi-arid tropics. The first ever comprehensive text to cover both the technical and the managerial aspects of afforestation, it formalizes many important concepts and presents many model designs for the management of afforestation projects.

It is designed for:

- Field level supervisors engaged in executing afforestation and tree planting programmes, such as forest rangers, agriculture extension officers, soil conservation officers, and junior engineers;
- Executive officers and managers entrusted with the task of planning, monitoring, and coordinating the activities of such programmes;
- Planners and policy makers in governments and donor agencies concerned with natural resource management and enabling community initiatives in the field;
- Students and teachers of forestry in universities, colleges, schools and other training institutions;
- Hobbyists, citizens, enterprise managers, business executives, industrialists, politicians, philanthropists, social workers and charity organizations interested in the global task of greening the planet.

It offers:

- A lucid running account of the technology of afforestation and tree



planting, ranging from nursery techniques to aftercare of plants in field;
- A basic organizational framework for managing large scale afforestation programmes, including model designs for enabling community participation in such progammes;
- Structured information in the form of charts, tables, figures, photographs, and model designs that can be used directly in planning new afforestation programmes and in planning and monitoring day-to-day activities in the execution of such programmes;
- A framework for a new and innovative one-semester course in afforestation technologies suitable for forestry colleges and universities.

The book can be used as a field manual. It can be an invaluable productivity enhancement tool by virtue of its instant designs, models, guides, drawings and other basic data. It will improve the quality of work done by workers and managers alike, and enable them to systematize and learn from their past experience.

The book has been conceived, designed, and written by a highly qualified author having nine years' practical experience in afforestation. The multidisciplinary background of the author in engineering, computer science, and forestry has led to a multidisciplinary systems approach that is at once unique and invigorating. The book incorporates five years' painstaking work in planning and organizing carefully researched data into structured information and practical designs.

Contents in brief:

Part I Technical Manual
Nursery techniques. Site selection, survey, and preparation of site plan. Design of the treatment plan. Execution of fencing work. Execution of soil and water conservation works. Execution of planting work. Aftercare and maintenance. Tending the rootstock. Dealing with problematic soils. Agroforestry in afforestation programmes.

Part II Management Manual
An organizational framework. Planning for time-critical activities. Monitoring, evaluation and review. Quality Control and productivity. Record keeping and documentation People's participation. Plantation management plan.

Part III Technical Charts and Tables
Silvicultural charts and tables. Charts and tables relating to nursery operations. Standard fence designs.

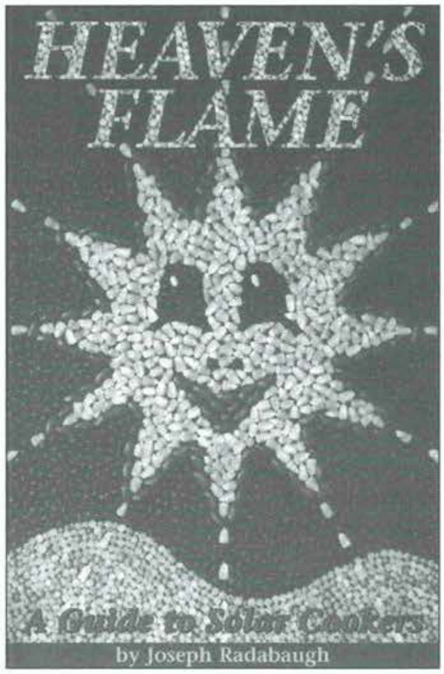
Standard designs of S&WC works. A model basic schedule rates. Model treatment plans and estimates. Units of measurement and conversion tables.

Part IV Management Charts and Tables
A model organizational structure. Networks, schedules and calendars. A model quality control programme. Information formats and MIS. Forms of record keeping and documentation. A framework for institution building. A model plantation management plan.

Part V Tree Planting Guide
A citizen's guide to tree planting
Photo-essay; Glossary of Technical Terms; Bibliography; Index.
For inquiries or further information please write to:

Customer Services Department
TreeCraft Communications
8A Kailashnagar, Jhotwara
Jaipur, 302 012
India
Orders and inquiries by phone/fax:
Phone: 91-141-340-333
Fax: 91-747-320 70

Heaven's Flame A Guide to Solar Cookers



The simple technology of the solar cooker is more important than ever before. In a time of surging populations and diminishing resources, this simple tool captures the light of hope, and feeds us with it.

Whether one is interested in conservation of energy and resources protecting the environment, self-sufficiency, health and nutrition, feeding the hungry of the world, or just the fun of learning about simple science, the solar cooker is the perfect hands-on tool. Imagine being able to cook a healthy meal, or tasty treats, using the power of the sun and a couple of cardboard boxes. This book explains all one needs to know to cook in one's own back yard using inexpensive materials and free solar energy.

Heaven's Flame, by Joseph Radabaugh, is a complete exploration of the art and science of solar cookers and solar cooking. From a who's who in the design and promotion of solar cookers worldwide, to tips and tricks for cooking delicious and health meals using the energy of the sun, this book has it all. Joe's technical but easy to read explanations gives one all the information needed to design a solar cooker. Easier still, Chapter Ten contains step-by-step instructions and illustrations for building the SunStar. This simple yet effective cooker can be easily constructed from recycled materials for only a few dollars. An easy and fun project, one can build an oven in an afternoon and cook with it the next.

Author Joe Radabaugh is a full-time designer, promoter, and user of solar cookers, raising his three children on solar-cooked meals. Since the early 1980s he has dedicated his life to spreading to the world what may be the most appropriate of all technologies. Joe travels extensively, educating all kinds of people in the simple wonder of cooking with the sun. Joe's 'simple is better' approach and his commitment to spreading the word has made *Heaven's Flame* perfect for educators and relief workers.

Heaven's Flame, (ISBN 0-9629588-2-4) is a second edition release, fully updated and revised, by Home Power Publishing. The book has 145 pages with over 200 black and white photographs and illustrations. At US$15 each (including shipping within the USA) one may be cooking with the sun for under twenty dollars.

To order a copy of *Heaven's Flame* contact Home Power Publishing, PO Box 275, Ashland, OR 97520. Inside the USA, call 800-707-6585, or from anywhere dial 530-475-0830. Order by fax at 530-475-0941 or on Home Power's web site www.homepower.com. Get this book, build a solar cooker, and eat good food cooked by the sun.

Forage Grasses and Legumes

L. N. Singh, A. Singh & J. Singh

This book *Forage Grasses and Legumes* gives morphological descriptions of 117 common tropical and temperate forage grasses and legumes. In addition, details of their adaptability, forage yield and quality are also presented. Over fifty photographs of different grasses and legumes are also included for their easy identification. A chapter is devoted to morphological structures of grasses and legumes presenting common terminology used for taxonomic description. Details of propagation methods, seed characteristics, seed rate, etc. provide valuable guidance for their establishment. Descriptions given about chemical composition of herbage, their digestibility, metabolizable energy and antiquality constituents are useful in understanding forage quality.

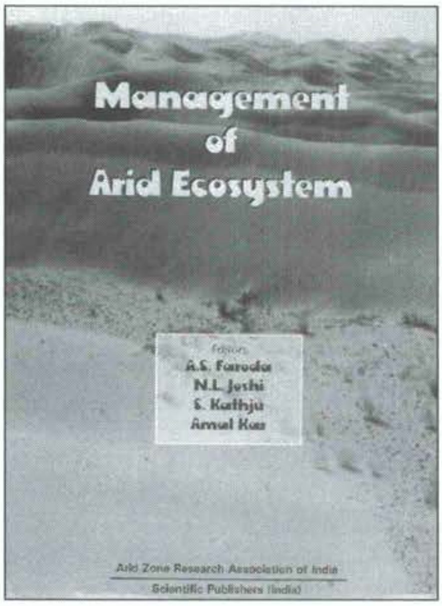
The book is very useful to field staff of agriculture, forestry and animal husbandry in the identification of different grasses and legumes, their selection for sowing in different agro-ecological situations and in knowing about their forage yield and quality. The book is also be useful to scientists and students of agriculture and animal husbandry in general.

ISBN: 81-7233-185-1

Scientific Publishers (India)
5-A, New Pali Road, P.B. No. 91
Jodhpur – 342-001

Management of Arid Ecosystem

A. S. Faroda, N. L. Joshi, S. Kathju & Amal Kar



The arid ecosystem has been under constant pressure from biotic and abiotic stresses throughout the millenium. In the last few decades there has been acute resource depletion of the already fragile ecosystem through over-exploitation of resources by the ever-expanding human and livestock populations and developmental activities. Realising the alarming situation, efforts were initiated a few decades ago by various national, regional and international organizations to contain the degradation processes and to restore the productivity levels in the arid ecosystem. Research in this direction has made great progress. The degradation processes are now much better understood and monitoring has been made possible, thanks to the modern tools available to researchers. There has been a shift in the concept from production capacity to sustainability of production systems.

Advances have been made in the last couple of decades to take stock of the recent developments in the field. AZRAI organized a symposium on 'Recent Advances in Management of Arid Ecosystem' in March 1997, attended by over 300 participants. For the benefit of those who could not attend the symposia of the 200 papers presented, 125 have been published in this book after they were peer reviewed.

The articles are grouped in seven major themes: (1) Natural resources appraisal; (2) Biodiversity and environmental conservation; (3) Sustainable crop production; (4) alternate land use systems; (5) Optimal water use; (6) Socio-economic factors and (7) Transfer of technology.

The book gives a broad but in depth and up-to-date coverage of problems related to arid zones. It is hoped that researchers and planners will find the book interesting and useful.

ISBN: 81-7233-217-3

Scientific Publishers (India)
5-A, New Pali Road
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Jodhpur - 342 001

News of Interest

Request for Articles and Photographs

The editorial board of the *Desertification Control Bulletin* is seeking photographs and articles for publication in the magazine. In particular, the editorial board is interested in receiving articles describing success stories in controlling dryland degradation and desertification, follow©up of the implementation of the United Nations Convention to Combat Desertification and NGO activities in the field of desertification control in all regions of the world, particularly in Africa.

The technical advisor is also seeking photographic submissions for use on the cover of the *Bulletin*. Photographs should be colour transparencies of subjects related to desertification, land degradation, humans, animals, structures affected by desertification, reclamation of degraded lands, etc. Please include a brief caption giving a description of the subject, place and country name, date of photograph and name of the photographer.

All contributions should be sent to:
Mr. Leonid Kroumkatchev
Technical Advisor
Desertification Control Bulletin
UNEP, DEIA & EW
P O Box 30552
Nairobi, Kenya
Tel: 254-2-623266
E-mail:
Leonid.Kroumkatchev@unep.org

For information regarding manuscript preparation, please see page ii of this issue of the *Bulletin*.

Submitting Success Stories to UNEP

UNEP is seeking projects or community-based activities that satisfy the above criteria/indicators of success as much as possible and which have been sustaining themselves without donor support for at least 2 years.

To submit a project/community-based activity for the "Saving the Drylands" award please send a 1-2 pages summary of the project/activity you are proposing with the following information in the given order: 1. Name of Project; 2. Country; 3. Location in country including biophysical descriptions; 4. Number of people involved; 5. Area (sq km) covered by the project; 6. Cost of project (US $ equiv.); 7. Source of funds; 8. Project period (years); 9. Problems; 10. Solutions; 12. Results/Impact; 12. Why the project is a success; 13. Names and addresses of three referees outside the project; 14. Contact person.

The contact

For more information on success stories or request for reports please contact:

The Co-ordinator,
Success Stories Initiative,
Social Dimensions & Sustainable Practices, PI
United Nations Environment Programme (UNEP)
P O Box 30552,
Nairobi, Kenya
Tel: (254-2) 623261; Fax: (254-2) 623284;
E-mail: elizabeth.migongo-bake@unep.org

Desertification is land degradation in arid, semi-arid, and dry sub-humid areas resulting from various factors, including climatic variations and human activities. This latest, internationally negotiated definition of **desertification** was adopted by the United Nations Conference on Environment and Development (UNCED), Rio de Janeiro, Brazil, in June 1992.

The United Nations Convention to Combat Desertification was formally adopted on 17 June 1994 and opened for signature in Paris on 14 October 1994. This Convention is notable for its innovative approach in recognizing the physical, biological and socio-economic aspects of desertification; the importance of redirecting technology transfer so that it is demand driven; and the involvement of local populations in the development of national action programmes. The Convention came into force on 26 December 1996.

UNEP

Desertification Control Bulletin
United Nations Environment Programme