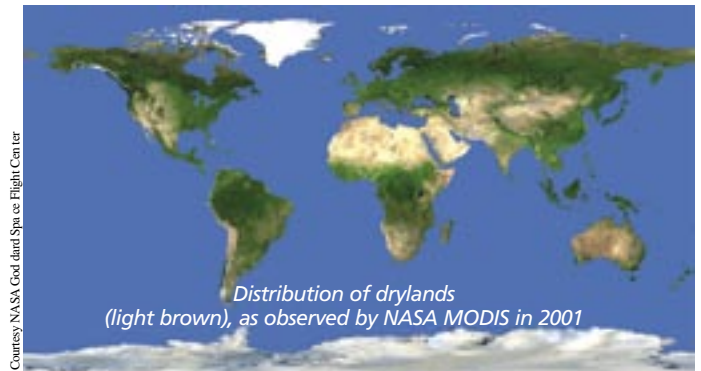


# The future of arid lands

Back in 1956, *The Future of Arid Lands*<sup>5</sup> predicted that drylands would receive renewed and sustained interest in coming decades. Drylands have been plagued by underinvestment ever since, regardless of the fact that advancing deserts continue to consume arable land at an alarming rate. Today, one-third of the Earth's surface is threatened by desertification and arable land is expected to shrink by two-thirds in Africa, one-third in Asia and one-fifth in Latin America by 2025 in relation to 1990.

A publication commissioned by UNESCO to mark the International Year of Deserts and Desertification, *The Future of Arid Lands – Revisited*, takes a critical look at the unintended consequences of past thinking on dryland ecosystems and the socio-economics of dryland development. What mistakes did we make and how can we learn from them? Due out in 2007, *The Future of Arid Lands – Revisited* argues for giving a new impetus to dryland research to fill the persistent gaps in our knowledge.



Paradoxically, the dryland climate in the low latitudes has much to recommend it as a place to live and a place to grow crops: clear skies, warm temperatures and long growing seasons. The key to making the desert bloom has always been finding water. With water at such a premium in drylands, the pursuit of new sources has been intense and unrelenting.

## Cloud seeding and other schemes

In the 1950s, there was a great belief in what future technology might deliver. The 1950s were the dawning of the era of large dam-building, whereas little attention was paid to groundwater as a major water resource. Water was to come from existing surface sources, from augmenting existing sources through cloud seeding (*see photo*) and other measu-

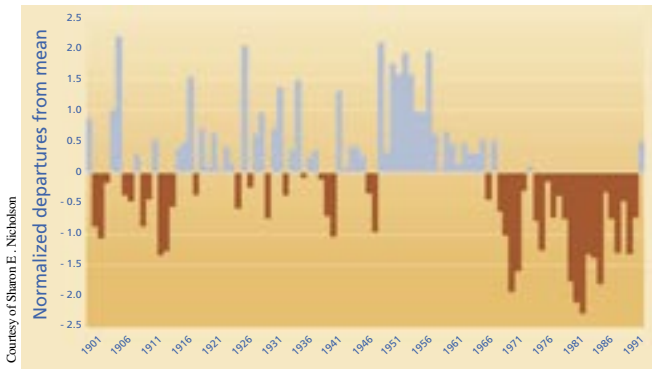
res, or from 'new' water originating from untapped sources, such as the desalinization of brackish water and seawater.

The intervening years have seen much of what was discussed then play out. Inevitably, though, many things have happened that were not foreseen. The 1950s marked the beginning of a period of unanticipated growth in water consumption in the agricultural sector in particular that has continued until today. Perhaps as a consequence of this rapid growth in consumption, there have also been some fundamental changes in the general perception of water development. While cost-benefit analysis was, and is, done for most water development projects, the scope of what is included among both costs and benefits has been broadened significantly since then from strictly economic costs to incorporate environmental and social costs as well.

Despite the fact that groundwater was largely dismissed as a major option in 1956, exploitation of groundwater resources developed rapidly from the 1950s onward, with most development taking place between 1960 and 1980. This development was mostly concerned with immediate returns on investment and not sustainability. Now, as the value of water is increasingly realized, markets have emerged as a mechanism for addressing inequities in the distribution of water through its direct sale and through the trade of commodities that represent water, or "virtual water."



Repeat satellite images of Almeria in southern Spain in January 1974 (left) and April 2000



Rainfall index showing standardized departures from mean annual rainfall compiled from meteorological stations in the West African Sahel between 1901 and 1994

In considering water development and water use as a whole, the most fundamental difference between 1956 and today is that focus has shifted from developing new water supplies to a more comprehensive effort to manage all water from an integrated perspective, both on the supply and the demand sides, and from a quality point of view.

### Modifying the weather and climate change

In drylands, where rainfall is often scarce but always variable, there has been a keen interest in understanding and being able to predict this variability and in finding ways to ‘make it rain’ when natural rainfall is inadequate. By the time *The Future of Arid Lands* was published, techniques for modifying the weather, like cloud seeding, were just emerging. Significantly, these were paralleled by the beginnings of numerical weather modelling using computers. The general view held that modifying weather and climate was a promising and appropriate means of furthering societal and even military goals. It proved to be possible to induce rainfall in very restricted situations over small areas but this technique was of such limited and often unpredictable value that it was largely sidelined after a good deal of research. However, it is still routinely pursued in some areas with the hope of marginally increasing water supplies, such as in the Colorado River basin in the USA.

Some 50 years on, the optimism that once surrounded our emerging ability to control climate and create more favorable weather in the drylands has largely given way to concern about undesired human impacts on global climate, such as global warming. Scientific and political discourse that once focused on purposeful weather modification has been replaced by debate over strategies for mitigating the impacts of inadvertent climate change and adapting to its consequences. With the growing awareness of the connectedness of large-scale atmospheric, oceanic and terrestrial systems, the focus of scientific interest has shifted from local and regional impacts to changes on a global scale. Temperature increases threaten the modest water resources of drylands in several ways. Clearly, increases in evaporation rates as a function of higher temperatures not only threaten reserves stored in reservoirs and soils but also increase water demand by plants. A more ominous threat for many regions may be that,

as minimum temperatures rise, lesser amounts of water will be stored in snowpack in the mountains surrounding many of the world’s drylands.

### The balance of nature versus the flux of nature

Ecology, maybe more than any other discipline, can be taken as an example of how paradigms develop. The process is not necessarily chronological with a new paradigm replacing an older one. Rather, schools of thought, or paradigms, fall into and out of favour with communities of practice. In ecology, the two most prominent paradigms are represented by the equilibrium (balance of nature) and the non-equilibrium (flux of nature) models of ecosystem behavior.

Ecological thinking in *The Future of Arid Lands* was dominated by the equilibrium paradigm, a model of ecological dynamics based on assumptions conceived in the context of northern temperate zones that had emerged early in the preceding century. Its validity as a framework for thinking about dryland environments was challenged almost from the very beginning, yet it came to dominate policy thinking for most of the 20th century. Today, though, dryland ecosystems are better described by non-equilibrium models, with disturbance, variability and unpredictability as accepted drivers. However, the equilibrium model persists institutionally and management in many drylands still follows an equilibrium approach.

The development of dryland ecology has further benefited from the emergence of, and advances in, complex systems science. Focus has now shifted from the study of individual components of dryland ecosystems – such as soil, water, vegetation and herbivores – to relationships and interactions among them.

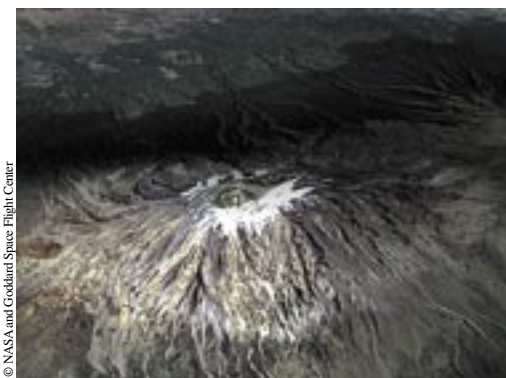
### Plant and animal alternatives

The primary focus of *The Future of Arid Lands* was plant and animal agricultural production. Only a handful of strategies were envisioned for improving drylands agriculture:

*Cloud seeding in New Mexico (USA) undertaken by Project Cirrus (1947–1952). Cloud seeding attempts to induce precipitation (rain or snow) by dispersing tiny particles such as silver iodide and frozen CO<sub>2</sub> (dry ice) as condensation nuclei into the air. This stimulates the formation of water droplets or ice crystals in the cloud. While cloud seeding with dry ice required an aircraft as seeding platform, silver iodide could be vaporized from the ground and borne up by air currents (photo: mobile silver iodide smoker mounted on an Oldsmobile). Cloud seeding is effective in reducing cloud cover but its capacity to increase precipitation is controversial. How can one know, for example, how much precipitation would have fallen from a cloud had it not been seeded?*



Repeat satellite images showing glacier retreat on Mount Kilimanjaro in the United Republic of Tanzania in 1993 (left) and in 2000. Last July, UNESCO's World Heritage Committee adopted a strategy for predicting and managing the effects of climate change on both natural and cultural sites, including Mount Kilimanjaro



© NASA and Goddard Space Flight Center

exploiting existing plant and animal resources; introducing crops and/or animals from other similar regions that might perform better than natives; or creating 'better' crops or animals through breeding or more advanced forms of genetic manipulation.

Some argued that larger animals were inherently more efficient than smaller breeds and favoured the camel as being 'ideal'; but the difficulty of expanding the market for camel products outside their traditional range was not discussed. It was generally agreed that more and better forage was the most critical element for livestock production. Thus, plant production became the primary focus both for rangelands and in agricultural fields.

Exotic plant species were seen as having great potential. A century or so of unwitting introductions had established that many plant species performed much better when introduced into areas outside their native range, particularly in areas with homologous climates. By 1956, there were programmes to reseed burned or degraded rangelands with exotic grasses.

Since then, exotic species use has been very controversial. In many areas, such as the Sonoran Desert of northern Mexico, large areas of native vegetation have been cleared and reseeded with exotic grasses (*see photo*). Many ranchers like their ability to colonize disturbed areas, outcompete native species and survive drought; they feel their land can now support more cattle. However, these very characteristics make these exotics undesirable in other parts of the region, where they are seen as a distinct hazard because they replace native species and introduce fire where it was previously unknown.

Many conventional crops are prodigious water users. There is a long history of seeking 'new' crops better adapted to arid conditions. Two different approaches to this search were discussed in 1956. One was to exploit native drylands plants with unique properties, like jojoba, a source of high-quality wax. The other was to selectively breed or engineer conventional crops for specific features, such as improved yield, drought tolerance, or disease resistance.

## The camel farm

Camels are often kept in excessive numbers in the open desert, putting a strain on desert vegetation. Camel farms may be the answer. By feeding camels farm-grown native desert plants, camel farms would enable the ecosystems of grazing rangelands to recover.

Camel farms could also reduce the amount of freshwater needed for milk production and save on electricity. Camel's milk does not need to be produced in an air-conditioned environment and a camel produces four times more milk per day (8 litres) in the open desert than a cow. (Cows can produce 25 litres of milk per day but only in an air-conditioned environment.) Producing native desert plants and halophytes as camel fodder would also use less freshwater than growing the *Alfa alfa* or Rhodes grass that camels currently eat.

One camel farm already exists in the United Arab Emirates, in Dubai. UNESCO's Doha office is developing a research project to study the pros and cons of establishing other camel farms.

Scientists working on the project will study such aspects as the nutritional and medicinal (dis)advantages of camel's milk versus cow's and goat's milk and the quantity of water needed to produce one litre of camel's milk in comparison

to one litre of goat's and cow's milk. The project will also study public attitudes to camel milk.

Scientists will study whether camel fodder can reduce the production of freshwater-dependent Rhodes grass and *Alfa alfa* by using the full range of farm-produced native desert plants (*Cenchrus*, *Pennisetum*, *Panicum*, *Rhanterium*, etc.), which will also be studied to determine how each influences the taste of the milk.

They will also study the genetic variety of camels in different parts of arid lands to ascertain whether (and which) camels can be fed with indigenous or halophytic (salt-tolerant) plants and still produce milk that is of good quality and plentiful.

The availability of oil and water has changed the way of life of the Arab bedu in both desirable and undesirable ways. Camel farming could help not only to rehabilitate the desert they call home but also to pull them out of poverty.

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Camels grazing rangelands in Qatar

©Hemming Schwanz/World Habitat Society

## The green revolution

Beginning in Mexico in the late 1940s, a host of advances were made in the development of improved crop varieties that were higher-yielding, more consistent in production and more resistant to pests. This led to the 'Green Revolution' in the 1960s, which helped to prevent famine in some parts of the developing world, including India. It did not benefit all people or all regions equally however. The Green Revolution has also drawn criticism for its focus on hybrid and genetically modified crops and the resulting loss of biodiversity, as well as for the health risks associated with the use of chemical pesticides.

In drylands, the first waves of the Green Revolution only reached areas that could be irrigated. Much of sub-Saharan Africa was largely bypassed. Part of this has been attributed to unreliable climate and lack of irrigation but also the inability of poor farmers to invest in the inputs, like fertilizers, that modern crop varieties demand. It has also been suggested that the late penetration of the Green Revolution into many of the world's drylands was due to a failure to invest in the exploration of local plant resources and establish appropriate local plant breeding programmes suited to marginal dryland environments.

Newer centres – such as the International Center for Agriculture in Dry Areas (ICARDA) and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) – confronted these specific obstacles. In sub-Saharan Africa, improvements in crops like millet, sorghum and cassava began to produce results in the 1990s. However, the modest gains experienced in many dryland areas were offset by general decreases in major grain prices, placing many dryland farmers in a double bind. It has been argued that continued investment in research by the international community is the only way for these farmers to 'catch up' eventually.



*Sorghum farmer in Burkina Faso*

By 1956, the work of the International Maize and Wheat Improvement Center (CIMMYT) had made Mexico self-sufficient in wheat production; this success spurred even greater interest in the genetic approach to increasing crop production (*see box above*).

Both these approaches have their limitations. During photosynthesis, plants take up CO<sub>2</sub> from, and give up water to, the atmosphere. This presents two constraints. Firstly, while plants can be engineered to be more water-efficient, there are fundamental limits to what can be achieved. Secondly, the adaptations many dryland plants have to reduce water loss also restrict their ability to take up CO<sub>2</sub>; many desert plants are not particularly water-efficient.

Furthermore, some dryland plants, such as jojoba, will not produce fruit during drought; if a crop is desired every year – something farmers expect – the plants must be irrigated often, thus negating some of their presumed drought-adapted advantage.

A third approach to using dryland plants was discussed in 1956 but has only really emerged over the past few decades. Dryland plants produce unique chemical compounds to deal with competition, heat, drought stress and predation. There are now programmes to discover and characterize compounds produced by dryland plants and associated microbes, to determine whether they have value for treating diseases such as cancer and HIV/AIDS.

Discussion in 1956 focused on identifying one crop, or some small suite of crops, that might transform dryland agriculture. Since then, research and development have come to focus not only on improving the plant and its environment through irrigation, fertilization and pest management but also on improving rural livelihoods and the physical, social and economic well-being of households and communities.

### Greening the desert

In 1956, the dominant strategy was to 'green the desert' by developing primarily surface water resources and extending large-scale irrigation systems to all lands that could be economically included. There was little concern with environmental and social impacts or water use efficiency. Maximizing the area under rainfed agricultural production was also a priority. However, it was understood that, because of climate variability, extending rainfed cropping into lands that had been previously devoted to grazing was risky. There was a great deal of concern in 1956 over possible negative impacts of traditional land use systems on drylands, particularly in developing countries. Livestock production, especially pastoralism, was clearly considered less desirable than cultivation and needed to be made more productive through the use of modern range management techniques. This, however, might involve 'improvement' by removing undesirable



*Repeat photography showing increasing abundance of mesquite on the Santa Rita Experimental Range in the Sonoran Desert in Mexico in 1902 (left) and 2003*

©ICRISAT

Santa Rita Experimental Range, University of Arizona

## Scientists pick priorities for curbing desertification

Each year, US\$2.4 billion is spent fighting land degradation in the world's drylands, a problem experts believe is likely to worsen. On 21 June, 400 scientists, experts and decision-makers from these regions identified research priorities in the Tunis Declaration. The Declaration was adopted at the close of a three-day meeting co-organized by UNESCO on The Future of Drylands, a landmark in the International Year of Deserts and Desertification. Areas of research singled out by the Declaration include: the interdependence and conservation of cultural and biological diversity, integrated management of water resources, the identification of sustainable livelihoods for the inhabitants of drylands, renewable energy suitable for dryland development, coping with and management of natural and man-made disasters and the costs related to inaction in fighting land degradation.

Read the Tunis Declaration: [www.unesco.org/mab/ecosyst/futureDrylands.shtml](http://www.unesco.org/mab/ecosyst/futureDrylands.shtml)



Tourist accommodation in Dana Biosphere Reserve (Jordan) at dusk. Ecotourism is one of several income-generating activities being fostered by the Sustainable Management of Marginal Drylands (SUMAMAD) project run by UNESCOMAB and the UNU. Other activities in Dana Biosphere Reserve involve the production of olive oil soap and jewellery-making for women specifically. In parallel, the project is improving the way in which irrigation is managed

vegetation through mechanical or chemical means and/or a reduction in stocking rates so that vegetation might recover. Either alternative was, and still is, expensive and probably not suited to developing countries.

Since then, strict distinctions among agricultural land uses have blurred. Agricultural research and development has focused increasingly on each use as one part of a larger system, thus exploiting synergies among these, such as agro-silvopastoralism. The value of land has also come to be determined by other considerations, including environmental, historical, social, cultural and spiritual values.

Attention has also been drawn to the negative consequences of some of the modern methods put in place decades earlier. The potential of salt accumulation in the soil was well recognized in the 1950s and the basic concepts of salinity management were known but solutions, such as drainage systems, were expensive. It was also believed that the process was easily reversed. Salinity management continues to be the main challenge facing irrigated agriculture. Furthermore, as concern grows over land degradation and desertification, large irrigation schemes are often viewed sceptically for their high financial, social and environmental costs and their potential to damage other sectors like fisheries, particularly in developing countries.



Rainwater harvesting in Burkina Faso using lowcost hand-constructed structures

Considerable progress has been made in increasing the efficiency of water use. Centre-pivot irrigation spread quickly from the 1960s onwards. In this system, sprinklers positioned on pipes rotate around fixed points (pivots) to irrigate circular fields. This technology allowed comparatively inexpensive irrigation virtually anywhere where water was available. It also allowed irrigation of a wide variety of terrains. Other advances have been made in conventional irrigation. On large scales, land levelling has greatly increased

water use efficiency. On small scales, the development of small portable pumps has allowed many farmers to ensure production during dry spells and to increase the number of cropping seasons per year. Development of drip irrigation has also increased water use efficiency, particularly in developed countries.

More recently, micro-irrigation techniques, which involve drip irrigation using buckets and inex-

pensive tubing, offer multiple potential benefits for small farmers in developing countries in terms of increasing yields while decreasing water, fertilizer and labour requirements.

In developing countries, rainwater harvesting through low-cost hand-constructed water control structures (*see photo*) is also receiving renewed attention as a means of promoting local self-sufficiency, reducing poverty and increasing food security where irrigated agriculture is not feasible. Such solutions are seen as potentially more sustainable, being based on local technologies and materials and generally requiring little cash investment.

As our skill in near-future weather prediction improves, more adaptive management policies will probably be required. For example, if we can predict good or bad growing seasons six months into the future, mechanisms must be in



This plant in flower in Qatar is a *Limonium axillare*, also known as beach lavender. It has a high salinity tolerance, making it a 'halophyte'. Scientists are studying ways of breeding halophytes and turning certain halophytes into agricultural crops. UNESCO's Doha office supported the publication this year of Biosaline Agriculture and Salinity Tolerance in Plants

place to advise and allow farmers and livestock operators to adjust their cropping or stocking strategies accordingly.

The primary objective in 1956 was to do 'better.' This implied more water and more agricultural production. Many development threads pursued after 1956 were clearly unsustainable, such as the exploitation of fossil groundwater in North America, North Africa and the Arabian Peninsula. Much of the improvement in system performance over the past 50 years may be technical, such as improved crop varieties but a great deal may also be related to policy, including trade, subsidies and tariffs.

### Why invest in drylands research?

**Firstly**, the problem described by Malthus<sup>6</sup> 200 years ago has not gone away. Over the next 40 years, the world's population will increase by 50% to 9 billion. Drylands constitute about 41% of the Earth's surface and will have to play a greater role in meeting these growing demands over the long term.

Most population growth will occur in developing countries, much of that in drylands and the bulk in urban areas. The challenge will be to develop safe, secure urban water supplies without causing undue harm to the agricultural sector – which would further encourage urban migration – or damaging the ability of the environment to provide goods and services for future generations. One opportunity is the reclamation and use of urban wastewater streams. Policy must acknowledge wastewater and stormwater as increasingly important resources.

**Secondly**, from a more immediate environmental perspective, it can be argued that significant parts of the world's drylands are the source of potentially serious global problems. Dust from the Saharo-Sahelian region of Africa and the drylands of central Asia is transported over continental scales and is of global concern. Dust from central Asia causes health concerns not only in China and Japan but also in North America. Dust from Africa may be contributing to the decline of coral reefs in the Caribbean.

## Quranic botanical gardens for the Arabian Peninsula

Botanical gardens are lacking in the Arabian Peninsula, despite their obvious value for conserving plant species ex-situ and the centuries old Islamic tradition of botanical studies.

Together with a team of architects, botanists, engineers, phytochemists and Muslim scholars, UNESCO's Doha office has designed a project to create a network of botanical gardens which will pay tribute to ancient regional traditions and cultures. These botanical gardens will display living plants mentioned in the Holy Quran, such as date palms, pomegranates, figs and grapes. They will also exhibit plants of importance to Islam, such as the medicinal plants used by the Prophet Mohammed and cited in his Sayings.

The gardens will educate the public about the need to preserve biological diversity. The victim of habitat loss, oil spills and inadequate livestock management practices, the flora of the rapidly developing Arabian Peninsula is in dire need of better protection from human influences.

The plans for the botanical gardens will respect the two major landscaping concepts of the Islamic gardening cultures. The first is based on typical desert environments, such as the Arabian concepts of wadi, baadiya, raudhas, sandy area and oasis. The second is characterized by plan-

ned gardens, such as the Persian concepts of sunken flowerbeds, *gulistan* (flower garden), *bustan* (orchard) or the quadripartite *chahar bagh*.

The core of the gardens will feature an orderly display of plants arranged in four quarters and divided by water canals, with a water fountain or basin at its centre. The plan of this core will be enriched by sunken flowerbeds, an ingenious traditional system motivated by the need for irrigation to reduce soil evaporation and plant transpiration.

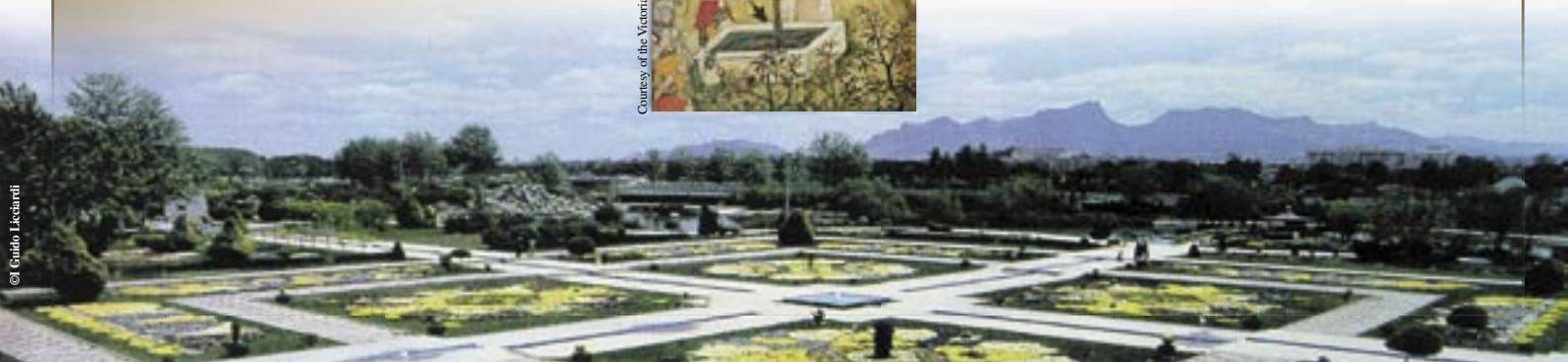
Around the core, each garden will conserve plants from different regional ecosystems. It will grow plants found on the coast, in mountainous regions, sandy areas, gravel deserts, the *wadis*, oases and aquatic habitats, as well as agricultural plants and halophytes (salt-tolerant plants). The project will be implemented over the coming year. Funds in trust agreements and workplans for each of the gardens are currently being discussed with potential donors.

For details, contact in Doha: [h.al-hammami@unesco.org](mailto:h.al-hammami@unesco.org)



Courtesy of the Victoria and Albert Library, London

(Left) The Emperor Babur supervising the construction of a garden illumination in the Baburname scroll (Below) Modern garden in Isfahan (Iran) based on the traditional quadripartite concept (*chahar bagh*)



## Fighting desertification with solar power



Girl selling charcoal at a market in Ougadougou (Burkina Faso) in 2000

© E.benchikh/UNESCO

Firewood remains the main source of energy (80%) in sub-Saharan Africa, where it is used primarily for cooking, lighting and heating water. People used to collect deadwood but, with the decline in tree cover, they are now having to resort to living trees. This practice, combined with the pressures of population growth, slash and burn land-clearing for agriculture and recurrent drought, is decimating Africa's forests, 10% of which are expected to disappear within the next 20 years.

In the Sahelian zone, the wind easily erodes the soil today because there is little vegetation to anchor the soil. The Eden Foundation, a Swedish NGO active in Niger, has observed that sand dunes can even be found in villages 200 km south of the Sahara, not because they have blown in from the north but because they have formed locally from eroded soil in places where trees have been felled to make way for annual crops like millet. The Director of the Department of the Environment in Niger was cited by the Eden Foundation in 1992 as saying that '250 000 hectares (equivalent to an area the size of Luxembourg) are being lost each year in Niger through desertification'. The Director added that 'firewood destined for the town of Zinder is collected up to 200 km away.'

Pilot projects have been run in recent decades to heighten awareness of the benefits of substituting wood for sustainable forms of domestic energy. In Africa, UNESCO's Renewable Energy Programme is supporting pilot projects to create 'solar villages'. Last year, UNESCO helped the Governments of Burkina Faso and Mali to install solar electricity in public facilities in remote villages, including rural health care centres and maternity hospitals. Particularly needed in the maternity hospitals was solar water heating to improve hygiene and thereby protect mothers and their newborn babies from life-threatening infections.

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Women in Mauritania using a solar cooker outdoors. In harnessing the sun's energy to cook food, solar cookers do away with the need to burn wood. They also save lives; every year, thousands of women die from inhaling poisonous carbon monoxide fumes given off by wood-burning in poorly ventilated dwellings

© E.benchikh/UNESCO

There is growing concern among researchers about potential effects of dryland dust on global climate as a result of reflection, scattering and absorption of solar radiation, and on cloud formation and precipitation.

**Thirdly**, from a global economic perspective, drylands have largely been marginalized. This is partly due to their physical isolation but is also a function of their lack of economic, political and social leverage within their respective countries. In some drylands that possess energy or other mineral resources necessary for global industry, this is not the case. In the future, due to their favourable location, climate, lack of competing land uses and correspondingly low land prices, drylands may also play a central role on the renewable energy stage as solar technology improves and costs decline. It is conceivable that drylands may enjoy other increasingly competitive advantages as suppliers of specialty crops or tourist destinations. Perhaps most importantly, it has now been shown that potential returns on investment in drylands are higher than in more humid areas.

**Lastly**, globalization is about more than just economics. There are issues of equity. Currently, 20% of the world's population consumes 85% of the world's resources. Many of the problems enumerated here are rooted, at

least partially, in poverty. Between 1997 and 2020, a combination of poverty and a deteriorating environment are expected to drive 60 million people from the desertic areas of sub-Saharan Africa towards northern Africa and Europe. Both environmental sustainability and the eradication of extreme poverty and hunger are Millennium Development Goals.

Charles F. Hutchinson and Stefanie M. Herrmann<sup>7</sup>

5. In 1956, the American Association for the Advancement of Science (AAAS) published *The Future of Arid Lands*. Edited by Gilbert White, it contains papers presented to international meetings of experts in New Mexico in 1955 to develop a research agenda on arid lands. The meetings were organized by the AAAS and sponsored by UNESCO with support from the Rockefeller Foundation
6. Thomas Robert Malthus was an English demographer and political economist best known for *An Essay on the Principle of Population* (1798). He predicted that population would outrun food supply on the basis of the idea that, if unchecked, population increases at a geometric rate (i.e. 2, 4, 8, 16, 32, etc.), whereas food supply grows at an arithmetic rate (i.e. 1, 2, 3, 4, etc.)
7. Both authors of *The Future of Arid Lands – Revisited* are affiliated to the Office of Arid Land Studies at the University of Arizona (USA)