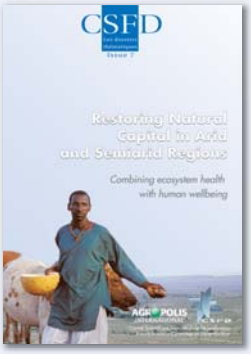
CSFD
Les dossiers thématiques
Issue 7

Restoring Natural Capital in Arid and Semiarid Regions

Combining ecosystem health with human wellbeing

AGROPOLIS INTERNATIONAL
Comité Scientifique Français de la Désertification
French Scientific Committee on Desertification



Les dossiers thématiques du CSFD Issue 7

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French Scientific Committee on Desertification

The creation in 1997 of the French Scientific Committee on Desertification (CSFD) has met two concerns of the Ministries in charge of the United Nations Convention to Combat Desertification. First, CSFD materializes the will to involve the French scientific community versed in desertification, land degradation, and development of arid, semi-arid and sub-humid areas, in generating knowledge as well as guiding and advising the policy makers and actors associated in this combat. Its other aim is to strengthen the position of this French community within the international context. In order to meet such expectations, CSFD is meant to be a driving force regarding analysis and assessment, prediction and monitoring, information and promotion. Within French delegations, CSFD also takes part in the various statutory meetings of the organs of the United Nations Convention to Combat Desertification: Conference of the Parties (CoP), Committee on Science and Technology (CST), Committee for the Review of the Implementation of the Convention. It also participates in meetings of European and international scope.

CSFD includes a score of members and a President, who are appointed *intuitu personae* by the Ministry for Higher Education and Research, and come from various specialities of the main relevant institutions and universities. CSFD is managed and hosted by the Agropolis International Association that gathers, in the French town of Montpellier and Languedoc-Roussillon region, a large scientific community specialised in agriculture, food and environment of tropical and Mediterranean countries. The Committee acts as an independent advisory organ; it has neither decision-making powers nor legal status.

Its operating budget is financed by subsidies from the French Ministries of Foreign and European Affairs and for Ecology and Sustainable Planning and Development as well as the French Development Agency. CSFD members participate voluntarily to its activities, as a contribution from the Ministry for Higher Education and Research.

More about CSFD:
www.csf-desertification.org

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Foreword

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Mankind is now confronted with an issue of worldwide concern, i.e. desertification, which is both a natural phenomenon and a process induced by human activities. Our planet and natural ecosystems have never been so degraded by our presence. Long considered as a local problem, desertification is now a global issue that affects us all, including scientists, decision-makers, citizens from both the South and North. Within this setting, it is urgent to boost the awareness of civil society to convince it to get involved. People must first be given the elements necessary to better understand the desertification phenomenon and the concerns. Everyone should have access to relevant scientific knowledge in a readily understandable language and format. Within this scope, the French Scientific Committee on Desertification has decided to launch a new series entitled *'Les dossiers thématiques du CSFD'*, which is designed to provide sound scientific information on desertification, its implications and stakes. This series is intended for policy makers and advisers from the North and South, in addition to the general public and scientific journalists involved in development and the environment. It also aims at providing teachers, trainers and trainees with additional information on various associated fields. Lastly, it endeavours to help disseminate knowledge on the combat against desertification, land degradation, and poverty to stakeholders such as representatives of professional, nongovernmental, and international solidarity organisations.

A dozen reports are devoted to different themes such as global public good, remote sensing, wind erosion, agroecology, pastoralism, etc, in order to take stock of current knowledge on these various subjects. The goal is also to set out ideological and new concept debates, including controversial issues; to expound widely used methodologies and results derived from a number of projects; and lastly to supply operational and intellectual references, addresses and useful websites.

These reports are to be broadly circulated, especially within the countries most affected by desertification, by e-mail (upon request), through our website, and in print. Your feedback and suggestions will be much appreciated! Editing, production and distribution of *'Les dossiers thématiques du CSFD'* are fully supported by this Committee thanks to the backing of relevant French Ministries and the French Development Agency. The opinions expressed in these reports are endorsed by the Committee.

Preamble

This CSFD special issue n°7 presents major features of the 'restoring natural capital' (RNC) concept applied to arid and semi-arid regions for the purposes of facilitating communication, information sharing and discussion. The goal is primarily: (1) to participate in promoting this approach to societies and communities most affected by degradation of the environments and resources they manage, and (2) to persuade governments and public and private assistance decision-makers to adopt this approach for their projects.

The present special issue is the result of a literature review of available scientific material concerning natural capital restoration in arid and semiarid regions. This topic has been the focus of numerous studies for several decades that gave rise to the concepts and definitions presented here. Most of these were adapted from the book published by Aronson *et al.* (2007a), which pools the contributions of 71 scientists, managers and journalists in the fields of ecology, economics and ecological economics.

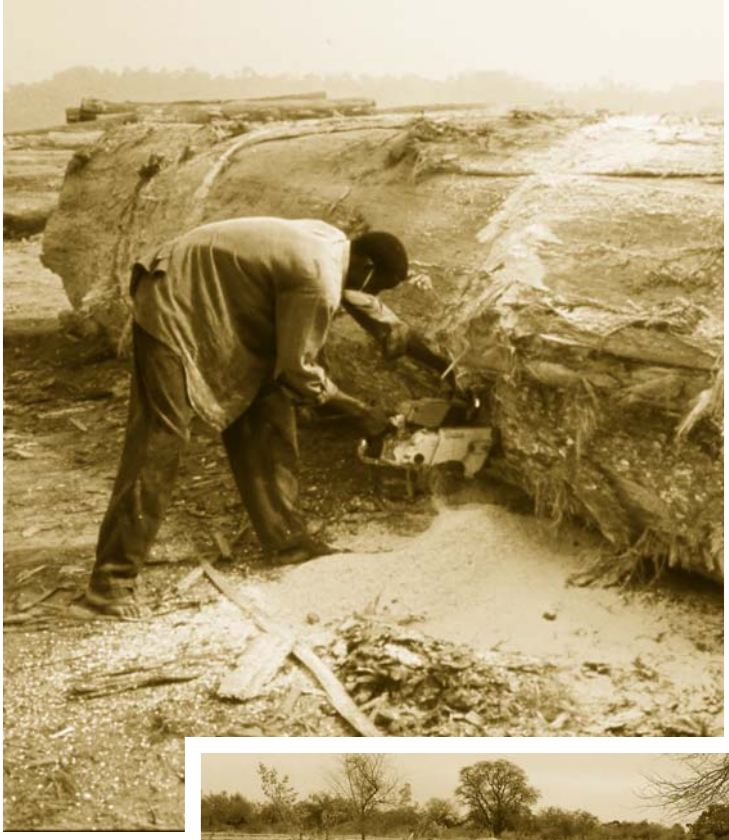
Several sites in arid and semiarid regions throughout the world are discussed to illustrate the elementary concepts of natural capital restoration through virtual field visits. These examples are from the book of Clewell & Aronson (2007) that was written to help people involved in activities of this budding ecological restoration profession.

These areas under harsh climatic conditions have been—and still are to an increasing extent—sites of social conflict for access to natural resources. The conflicts are further aggravated by the extreme poverty and marginal living conditions that prevail, and triggered mainly by poor management of vital natural capital such as water, land and plant resources (rangelands, fuelwood, etc.). Even these very basic needs are currently not being fulfilled. The moment is hence now ripe to design and promote the adoption of an alternative approach to environmental management that is socioeconomically fair and ecologically sustainable.

Profound changes in the behaviour of our societies (from field operators to policymakers) with respect to the natural environment are required before such an approach can be successfully implemented. These changes will be difficult and not sufficient to fulfill communities' basic needs if they are not combined with efforts geared towards restoring the already substantially degraded natural capital, which in turn is known to lead to the deterioration of human and social capital. It is thus recommended that social capital restoration also be promoted to ensure that natural capital restoration projects will succeed.

Facilitation of information flow, sharing and communication on the concepts (especially scientific) underlying the RNC approach is essential. Responses to further questions covered in this special issue, e.g. who should provide investment for restoring natural and social capital, or how to provide long-term ecological monitoring and follow-up, are provided in previous CSFD special issues. Social demand for the restoration of degraded ecosystems is generally low despite the ongoing environmental degradation and biodiversity loss, so preserving genetic resources should be a key priority to ensure that ecological restoration projects will come to fruition.

Édouard Le Floc'h
Former researcher, CEFE/CNRS
Former CSFD member



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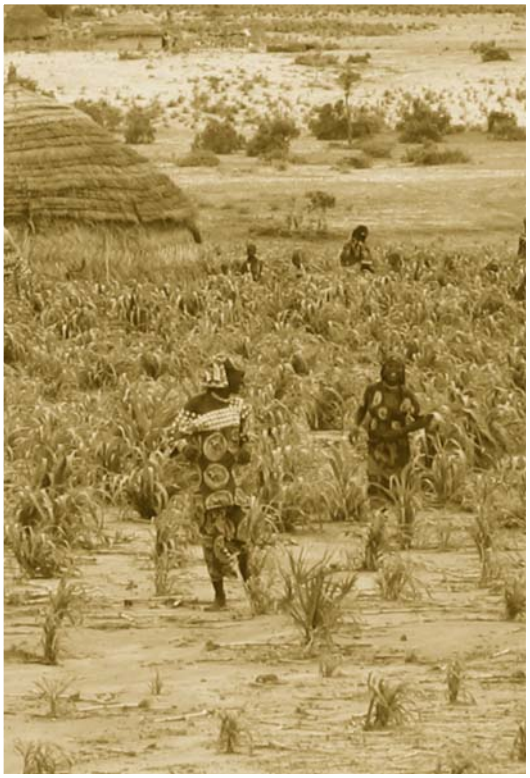


Restoring natural capital: an ecological and socioeconomic imperative

Humanity's **ecological footprint** is currently much greater than the Earth's carrying capacity. This means that the natural resource consumption rate, the environmental degradation rate and the extent of pollution emission due to the frantic tapping of these resources are higher than the renewal and absorption rate of **ecosystems**. Humanity, for the first time in its history, is devouring these reserves, which in turn is giving rise to tightly linked ecological and humanitarian crises worldwide.

An ecological crisis arising from an economic system

The ecological crisis mainly involves loss of **biodiversity**, shrinkage of natural areas and degradation of **ecosystem functionality** on local, regional and global scales (MEA, 2003). The new environmental conditions created by this crisis have especially led to global warming and a reduction in readily accessible drinking water (Vitousek *et al.,* 1997; Wackernagel *et al.,* 2002).

It is currently acknowledged that humans—via the economic, social and cultural systems and structures to which they belong—are accountable for this degradation (Makhlouf, 1995), despite the direct impacts on humankind, including the worsening of conflicts for resource access and the loss of **natural goods and services** (e.g. wood supplies, carbon sequestration, etc.). These goods and services provided by ecosystems are nevertheless essential for societies' survival and development. The ways we utilize and distribute natural resources therefore have to be reshaped.

In the current demographic and economic setting, preservation of natural resources alone is not enough to fulfil humans' fundamental needs for goods and services. Global **natural capital** is actually already too low to continue sustaining most economic systems in developed countries. **Ecological restoration** of degraded ecosystems is necessary. However, it will be futile if such initiatives are not combined with setting up sustainable resource exploitation systems and if our consumption habits are not thoroughly modified (Aronson *et al.,* 2007a). Experience has shown that restoration projects are bound to fail if they are not focused also on rectifying the ways resources are utilized, i.e. the renewed resources will be overtapped and again degraded since the initial causes still persist (Makhlouf, 1995).

In arid and semiarid regions, land degradation due to overuse is often the result of the insecure socioeconomic conditions that prevail—meeting the basic food needs of humans and livestock herds is a prime concern.

The humanitarian crisis: biosphere degradation deals a heavy blow to the poorest people

Natural goods and services are currently exploited and distributed at the expense of the poorest population groups (MEA, 2005). The resulting unfair distribution of profits further accelerates massive ecosystem degradation. The poorest people are often obliged to use highly environmentally destructive practices to

A gigantic log being cut up with a chainsaw near the San-Pédro logging harbour, Côte d'Ivoire.
P. Haeringer © IRD

procure sufficient resources to meet their vital needs. The resulting depletion of natural resources quickly amplifies the insecurity of these populations. In degraded environments in developing countries, users of the already rare resources cannot risk implementing more sustainable exploitation methods when they are competing directly for increasingly scarce resources.

This vicious circle is partially fuelled by **economic globalization** and by the fact that resources have to be accessed from ever more remote areas. The richest populations are no longer interested in resource exploitation methods and their potential impacts on the environment. However, this situation could be corrected if:

- Methods are developed for economic assessment of the costs and benefits of an alternative approach to natural resource exploitation, conservation and distribution.
- Users (individuals or groups) are made accountable for the resource, while being provided with the technical and financial means necessary to implement sustainable resource management methods.
- Resources are fairly redistributed so that the user will get a **return-on-investment**.
- Consumer resource accountability and awareness are boosted worldwide.

Focus

The ecological footprint: the environmental impact of our lifestyles

The ecological footprint concept was developed in the early 1990s by William Rees and Mathis Wackernagel (1994) at the University of British Columbia.

The ecological footprint calculation can be used to estimate the natural capital demand required by a given human population to maintain its lifestyle. The calculation method is based on a reinterpretation of the carrying capacity concept while also taking the economic setting into account.

The carrying capacity refers to the maximum number of individuals of a species that a given habitat can support over an indefinite period, e.g. the size of a human population living in an isolated region. However, different regions inhabited by humans cannot be taken as independent units since, via commercial trade, their economies have become globalized. The question of the quantity of individuals that a given region can sustain is therefore no longer relevant for human populations. Instead, the question should be: What is the land and/or sea area required to sustain a flow of resources to fulfil a population's consumption needs in a given region? This estimated land and/or sea area (regardless of where it is located) is the population's ecological footprint. It is a physical measurement of the natural capital demand of a given population.

The World Wide Fund for Nature (WWF) is now promoting this measurement by offering anyone interested, in addition to other features, a tool to calculate their personal ecological footprint online (http://footprint.wwf.org.uk) while also suggesting ways to reduce it.

This ecological footprint concept is a good way to boost public awareness on the environmental impact of our lifestyles and on how precarious our situation is on Earth. For instance, in terms of its global ecological footprint, humanity was using 1.2 times the Earth's biocapacity in 2001 (WWF, 2004)!

An extensive rangeland with a brown vertisol developed on calcareous shale. Erosion is due to overgrazing. New Caledonia.
B. Bonzon © IRD

The **restoration of natural capital** (RNC) is thus a key strategy for dealing with these two crises. This new approach is geared towards meeting ecological restoration objectives while enhancing the wellbeing of human populations from a socioeconomic standpoint. RNC thus bridges the gap between the imperatives of: (1) biodiversity conservation and **ecosystem health** protection, (2) short-term local production, (3) **economic development** on national and international scales, and (4) **Sustainable local economic development.**

Restoring natural capital: a focused response

Ecologists, nature conservationists and economists all have different viewpoints on ecological restoration and sustainable development goals. It is essential to come to a consensus on the definition and interpretation of these key terms so as to be able to effectively inform communities and their representatives on the objectives and impacts of current and future policies.

Economic growth nowadays takes precedent over the preservation of natural ecosystems (de Groot, 1992), i.e. increasing production (or the 'size' of the economy) leading to increased consumption (Daly and Farley, 2004). This political option is based mainly on the fact that biodiversity conservation, poverty alleviation and economic development are generally considered to have independent and often conflictual interests. RNC—as we will see throughout this special issue—aims to pool these *a priori* different interests. It meshes ecological restoration and sustainable development so as to tap the respective benefits of both approaches.

Around 40% of all emerged land on Earth is under threat of desertification and acute poverty generally prevails in these areas (Requier-Desjardins and Caron, 2005). An approach aimed at restoring ecosystems as well as the living standards of local people in arid and semiarid regions is therefore necessary. The concepts concerning natural capital and its restoration are outlined in the following chapters.

Focus

Desertification and its impact on humans

The United Nations Convention to Combat Desertification (1994) defines the desertification process as *"land desertification in arid, semiarid and dry subhumid areas resulting from several factors, including climatic variations and human activities."*

Unpredictable climatic conditions (recurrent drought and irregular rainfall), combined with the need to immediately fulfil local peoples' food and energy needs (using practices that are ill-adapted for utilizing natural resources), generally leads to severe environmental degradation. This phenomenon includes destruction of the plant cover (grazing areas converted to crop land), a reduction in soil fertility, ecosystem modification and an increase in conflicts to control natural resource management (Requier-Desjardins, 2007; Requier-Desjardins and Caron, 2005).

Increased population growth and insecurity also lead to heavy unsustainable exploitation of natural goods and services. The pressures placed on ecosystems disrupt the balance between the demand and the production of these goods and services, thus forging conditions that are conducive to desertification.

However, the causes and processes responsible for desertification are variable. They depend on the worldwide (global warming), regional (geographical and political area) and local (landuse practices and management) settings. International directives, regional policies and local initiatives are thus required to combat desertification. These three scales (global, regional and local) are tightly interdependent (MEA, 2005). It is also crucial that initiatives implemented to solve local problems be tailored specifically to local peoples' demand (needs, objectives, values).

What is natural capital?

The natural capital concept was shaped in the late 1970s (Jurdant *et al.,* 1977) and then further developed by Costanza and Daly (1992), and others. This concept is essential in promoting environmental issues to ensure that they will be taken into consideration in economic decision-making processes. The natural capital term also reflects the limiting role of natural resources and ecosystems in peoples' and nations' socioeconomic development (Ekins *et al.,* 2003). We will first explain the different types of existing capital so as to fully clarify the term 'natural capital'.

Different types of capital

There are five types of capital (MEA, 2005):

1. **Financial capital:** money and its substitutes.
2. **Manufactured capital:** buildings, roads, and other human-produced, fixed assets.
3. **Human capital:** individual or collective efforts and intellectual skills.
4. **Social capital:** institutions, social relationships, social networks, shared cultural beliefs and traditions.
5. **Natural capital:** an economic metaphor representing the stock of natural resources from which goods and services upon which human societies depend are derived. There are four types of natural capital: (a) renewable natural capital (living species, ecosystems), (b) nonrenewable natural capital (petroleum, coal, diamonds), (c) replenishable natural capital (the atmosphere, drinking water, fertile soils) and (d) cultivated natural capital (crops and forest plantations).

Natural capital (as defined by Daly and Farley, 2004) thus includes all sustainable ecosystems and ecological landscapes from which humans cull services and products (goods) that enhance their wellbeing without production cost. It should be noted that all cultivated natural capital and manufactured capital stock derives from renewable, replenishable or nonrenewable natural capital.

Renewable natural capital is the structure and composition of natural ecosystems which, through their functioning, yield a flow of natural goods and services to benefit humans. Replenishable natural capital corresponds to stocks of nonliving resources that are constantly recycled via interactions with living resources over long periods. Finally, cultivated natural capital represents agroecological production systems that are more or less self-sustaining, depending on how they are managed.

For several decades now, the rate of natural capital utilization (degradation) has been greater than its renewal rate. Processing this capital into manufactured goods is gradually (but to an increasing extent) destroying natural resource stocks and ensuing goods and services.

Loss of natural capital can also lead to a concomitant decrease in social and human capital (Aronson *et al.,* 2007a). This is especially true in arid and semiarid areas where the steady reduction in natural services resulting from desertification fosters outmigration and loss of affected peoples' self-esteem, in addition to political conflicts (Requier-Desjardins and Caron, 2005).

Wooded savanna with termite mounds, Cameroon.
F. Anthony© IRD

The interdependence of these different types of capital should be put forward in desertification control efforts and RNC in general. The degradation of land and quality of life are indeed linked (MEA, 2005), as is their restoration. This interdependence must be contemplated in order to overcome the preconceptions that prevail concerning these processes, which are stumbling blocks to finding solutions to environmental and socioeconomic problems.

Nature conservation *versus* economic growth?

Nature conservation and restoring ecosystem health are conventionally viewed as being incompatible with or even contradictory to economic development goals. The following table underlines the contradictions that may arise with a too narrow vision of ecology and economy. This table also highlights the benefits of an approach that combines ecological restoration and sustainable development. It is now necessary to review the ideological differences between the economic growth and sustainable economic development concepts in order to understand the natural capital restoration setting overall. These differences are discussed in the following chapters.

Restoring natural capital: bridging the disciplinary and ideological divide between the natural and social sciences

Source: Aronson *et al.*, 2007b.

Topics/ Viewpoints	Extreme environ-mentalism	Neo-classical economics	Contri-butions of RNC to bridge the economy/ ecology divide
People	We are too numerous and consuming too much (for the wellbeing of other species).	Making choices based on individual interests.	Reconciling individual and collective needs and those of current and future generations.
Vision of the economic future	Deeply pessimistic, unless radical changes have taken place.	Optimistic, linear, deterministic.	Steady-state economics that recognize ecological limits to growth.
Humans part of Nature	Belonging to Nature.	Humans outside of natural ecosystems.	Humans and Nature constitute socio-ecosystems.
Determining the value of natural goods and services	Intrinsic value of all living entities.	Utility value, determined by market prices.	Multi-valued because the material economy depends on ecosystem health.
Conducting standards and standards of conduct	All living species merit respect and attention.	Cost-effectiveness, personal and utility interest.	Biosphere respected on the basis of sustainable socioeconomic wellbeing.
Capital substitution	No substitution possible for natural capital.	Complete substitution possible between natural and manufactured capital.	Partial substitution, natural and manufactured capital are complementary.

Focus

Elastic model: relationship between natural capital and growth

■ Step 1

The production function has four factors: natural, technical, human and social. The income level W (represented by ☺) depends on the pooled quantity of the four capitals. In this graphic representation, the W level is 'attached by elastics' at the tip of the four capital stock 'pillars', thus illustrating the production function W= f (N,T,H,S).

■ Step 2

There are many known examples where growth is based on natural capital consumption. In Africa, for instance, the cropping methods used deplete the soils of their fertility and are generally not tailored to meeting the needs of the growing population. Natural capital thus gradually declines, along with crop yields, until a specific threshold S is reached beyond which soil fertility, and especially yields, collapse.

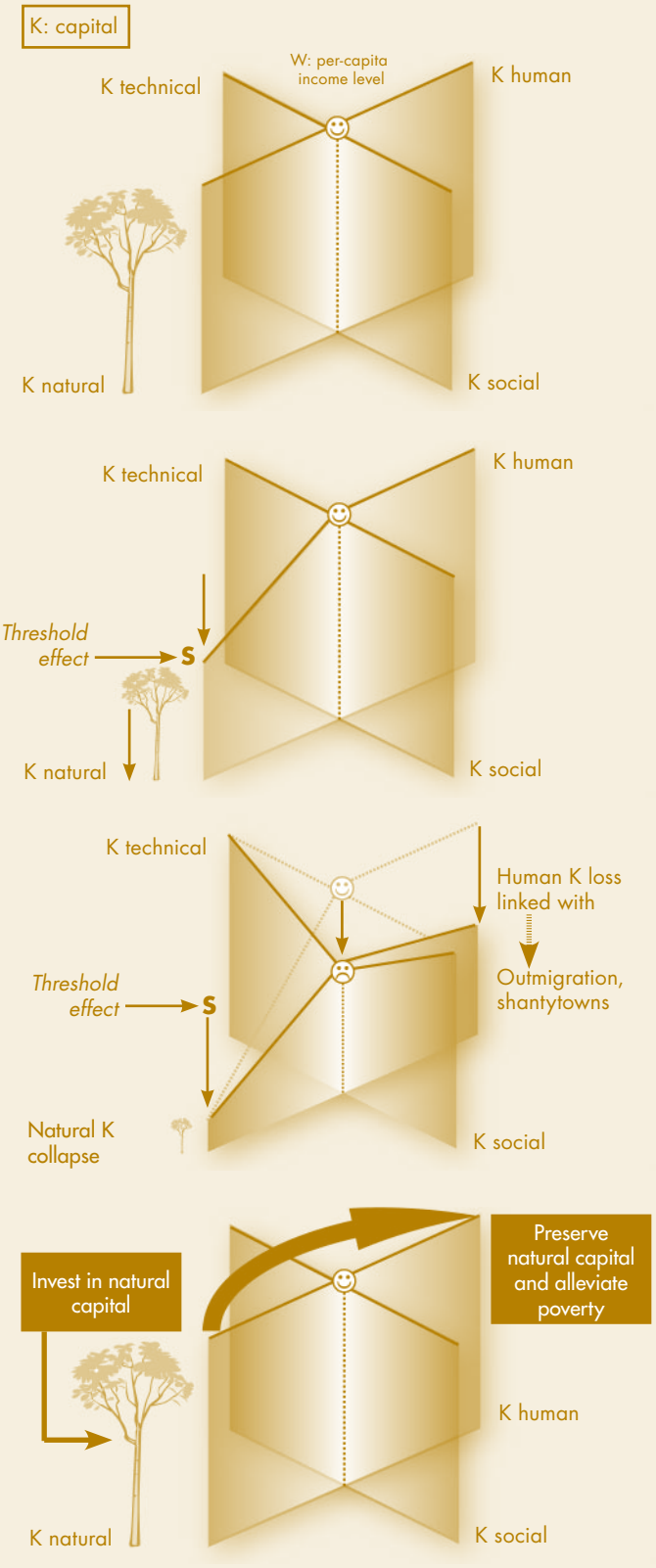
■ Step 3

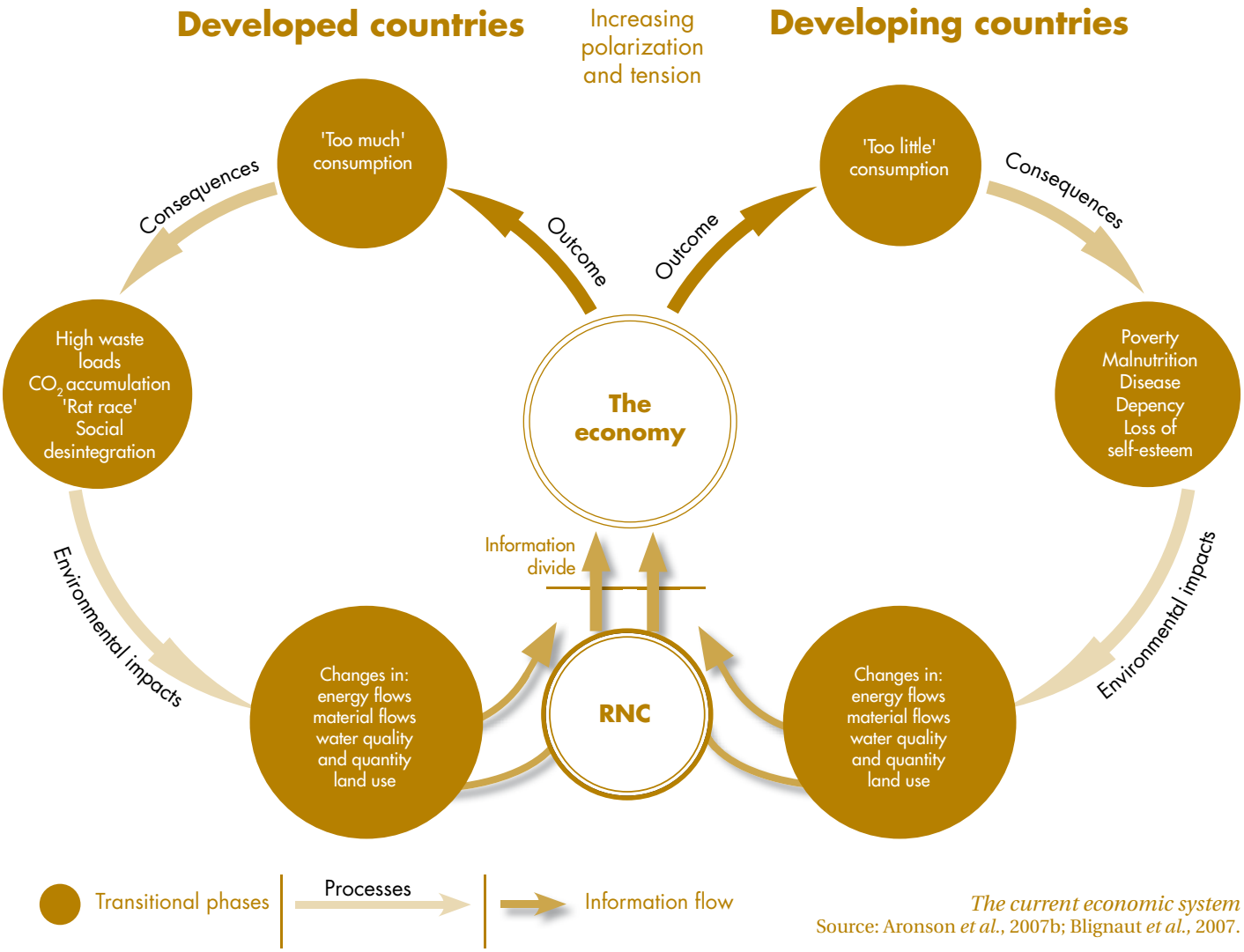
The soil becomes sterile beyond the S threshold. Farmers then fall into the unskilled labourer category and are obliged to seek other work. The value of his/her human capital thus declines, i.e. the farmer can no longer make effective use of his/her knowledge and experience (know-how, adapted sowing methods, etc.)—this negative externality reduces the natural capital to a level that is insufficient for the farmer's human capital, leading to a concomitant reduction in income.

■ Conclusion

This representation highlights the fact that investment should be promoted before the S threshold is reached, so as to halt natural capital depletion and stall progress towards the threshold—the social cost-effectiveness of such investment will be very substantial. These threshold phenomena induce nonlinearities in the growth process, which are clearly hard to model.

Source: Girault and Loyer, 2006.





The current economic system
Source: Aronson *et al.*, 2007b; Blignaut *et al.*, 2007.

Natural capital: a sustainable development limiting factor

We have seen earlier that human populations depend on goods tapped from ecosystems (wood, etc.), as well as natural services required for their survival and the stability of their societies. These services are derived from the natural capital stock. Most of these services are free and nonproprietary, i.e. an individual's consumption of a service does not reduce the capacity of other individuals' consumption of this service (e.g. through an increase in price or a reduction in access). Reference is sometimes made to global public goods (Requier-Desjardins and Caron, 2005). This **public goods** concept underlines the fact that the consumption of one good does not limit the consumption of others, and that the quality of the service does not decline as a function of the number of users (i.e. nonrivalry). In practice, because of these different features, there are no economic signals concerning the reduction in ecosystem services (Farley and Daly, 2006). They have no current economic market value (cf. above figure).

This diagram represents a simple model of the current economic system, while highlighting the economic divide between developed and developing countries. Information concerning environmental changes and their impacts on our societies is not mainstreamed into the system. The RNC approach fosters this flow of information between developed and developing countries and relative to the predominant global economic system.

The aim of the predominant economic system is to maximise individual consumption via economic growth. This growth involves a physical increase in the rate at which the economy transforms natural resources into monetary value (manufactured capital) and waste. Waste emission (or pollution) is not accounted for in production costs, so it is currently more cost-effective to invest in natural capital depletion than restoration.

Agriculture in Tunisia. Sorting dates harvested in southern Tunisia.
V. Simonneaux © IRD

Contrary to economic growth, economic development involves an increase in peoples' wellbeing and quality of life for a given level (constant rate) of natural resource transformation. For sustainable economic development:

- The rate of natural capital transformation into manufactured capital should not exceed its renewal rate.
- The quantity of waste emitted should not exceed the natural absorption capacity of the biosphere (Daly, 1990).

The sustainable development concept fosters the fulfilment of humans' basic needs while preserving natural services that are essential for life on Earth (Kates *et al.,* 2001). This concept incorporates the fact that our economy is limited by the functioning capacity of ecosystems within the biosphere. This does not mean, however, that peoples' quality of life should be relinquished in favour of nature conservation. To the contrary, sustainable local economic development is correlated with the enhancement of local and neighbouring peoples' well being.

To restore and improve relationships between humans and the natural environment, it is important to:

- dissociate economic growth (increase in the 'size' of the economy) and economic development (increase in quality of life for a constant 'size' of the economy) concepts;
- take the functional limits of global ecosystems into account.

Manufactured capital is no longer the limiting factor for the economy—it is natural capital. By economic reasoning, investment should be focused on the limiting factor (Aronson *et al.,* 2006a; Costanza and Daly, 1992) so, in society's best interest, there should be heavy investment in restoring natural capital. Different methods for economic valuation of natural capital and associated goods and services have been developed to promote this investment. These are covered in the chapter on the socioeconomic benefits of restoring natural capital in arid regions (page 18) but, as a prelude, the concepts underlying the implementation of natural capital restoration in arid regions are described in the next chapter.

Focus

The global public goods concept based on economic precepts

A global public good (GPG) is, for economists, a good that can be consumed by anyone—its consumption by one person will not be detrimental to that of other people (e.g. the air we breathe). GPGs can be supplied by the private sector or by States, e.g. crown forests are public goods which are managed by the States that own them.

Biodiversity, i.e. some outstanding forests and sites, may also belong to private stakeholders who thus contribute to the production of pubic goods. GPGs are goods whose products and costs extend beyond geopolitical boundaries and generations.

Source: Requier-Desjardins and Caron, 2005.

On the outskirts of a village, a small-scale factory for making bricks from a mixture of clay, straw and water. The bricks are sun dried. Sikasso region, Mali.
M. Dukhan © IRD

What does restoring natural capital involve?

Restoring natural capital is a novel management approach based on the interdependence between human wellbeing and ecosystem health. Restoring goods and services associated with arid and semiarid environments is essential in combating desertification.

Restoring natural capital: ecosystem health and human wellbeing in arid and semiarid environments

Restoring natural capital (RNC) concerns all activities that involve an increase or investment in natural capital stock with the aim of boosting the flow of natural goods and services, while also enhancing human wellbeing (Aronson *et al.*, 2006). Like restoration ecology, RNC is geared to improving ecosystem health and **resilience** (Clewell and Aronson, 2006, 2007), and addressing peoples' socioeconomic expectations.

RCN may include (but is not limited to):

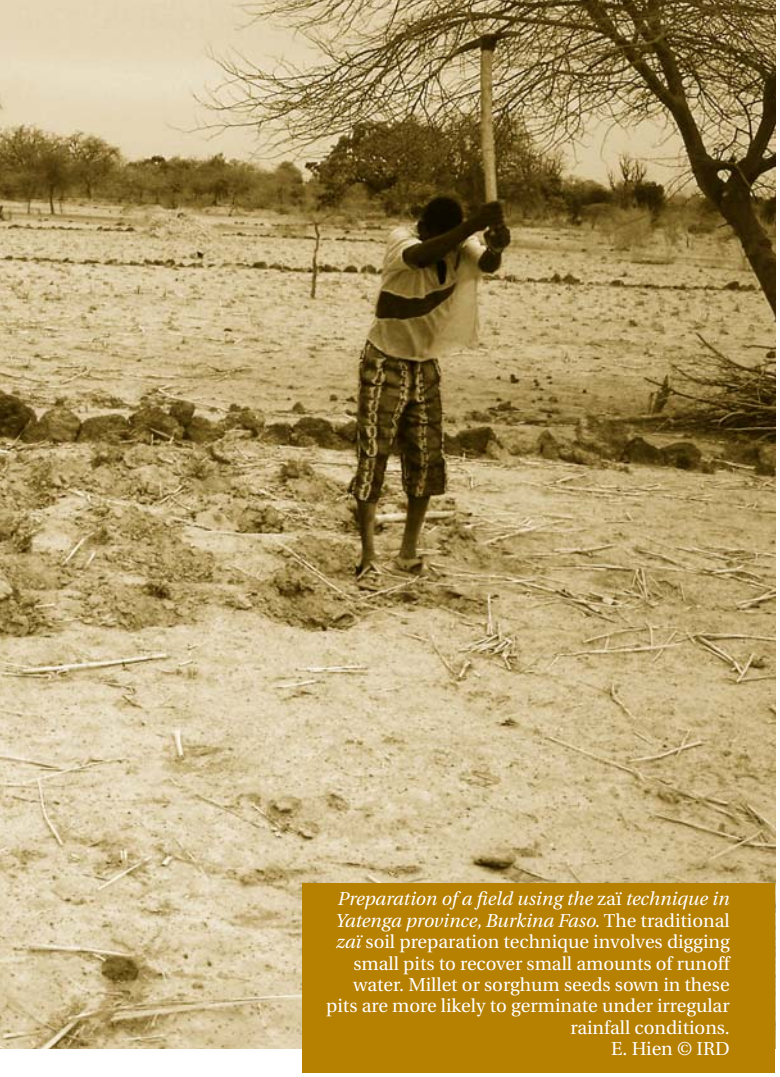
- restoration of terrestrial and aquatic ecosystems;
- sustainable ecological improvement of land subjected to cultivation or any other management practice;
- promotion of sustainable biological resource use;
- setting up or enhancing socioeconomic activities and habits that incorporate environmental considerations and sustainable natural capital management.

As already discussed, ecological restoration is aimed at recovering the productivity and enhancing the biodiversity, stability and resilience of degraded ecosystems. This can be done by restoring ecosystem functions (i.e. all goods and services).

It is hard to pinpoint exactly how these functions affect the stability of human societies prior to their degradation. However, the extent of this impact could be determined by clarifying the effects after social degradation has occurred. In arid and semiarid environments, Le Houérou (1995) listed eight ecological consequences of desertification:

1. Reduction in organic matter production and litter incorporation, leading to a reduction in the productivity and fertility of soils and ecosystems.
2. Formation of a soil cap: a crust that forms on the surface of bare soils under the impact of rainfall and which hampers water and seed penetration in the soil.
3. Formation of a biological crust of algae, lichen or moss whose effects resemble those of soil caps.
4. Dry mechanical erosion due to sliding of particles down slopes via gravity. This is the result of constant ploughing on steep slopes.
5. Wind erosion.
6. Wind deposition: the formation of sand or clay dunes following wind erosion.
7. Water erosion.
8. Anthropogenic salination: a phenomenon resulting from ill-adapted irrigation, leading to soil sterilisation.

Restoring these functions is a complex process. Conceptual working frameworks or models are available to gain insight into the phenomenon and facilitate communication between different RNC stakeholders. For instance, the TTRP model developed by Tongway and Ludwig (2007a and b) has proven useful in solving environmental problems in Australia.



Preparation of a field using the zaï *technique in Yatenga province, Burkina Faso.* The traditional *zaï* soil preparation technique involves digging small pits to recover small amounts of runoff water. Millet or sorghum seeds sown in these pits are more likely to germinate under irregular rainfall conditions.
E. Hien © IRD

Focus

TTRP model used to assess grassland ecosystem functioning in semiarid regions

Tongway and Ludwig designed a conceptual framework to facilitate the restoration of grassland landscape functions in semiarid areas. This so-called the trigger-transfer-reserve-pulse (TTRP) model is based on two main features of semiarid regions: (i) high spatiotemporal heterogeneity in resource availability, and (ii) low unpredictable rainfall conditions.

Through a series of simple steps, the TTRP model highlights certain processes involved in natural capital formation. It helps to identify the most suitable level at which restoration could take place. A 'trigger' event like rainfall initiates the water transfer process: loss ❸ and reserve storage ❶. If the water reserve is sufficient, plant growth, accompanied by livestock production and microbial mineralisation, is initiated ❷. Many biological, chemical and physical processes are then set in motion, such as organic matter formation, nitrogen fixation, carbon sequestration, microbial and macrofauna activities and soil nutrient transformation.

These processes promote an increase in natural capital, and its transformation and recycling ❺. The formation of soil pores and galleries by macrofauna, for instance, boosts water infiltration and supply, while enhancing root and microbial respiration.

Examples of processes involved

❶. Flow, storage, salinisation
❷. Seed germination and plant growth, mineralisation
❸. Outflow to rivers, erosion
❹. Grazing, burning, harvesting
❺. Replenishing the seed bank, Organic matter cycling
❻. Physical obstruction, absorption

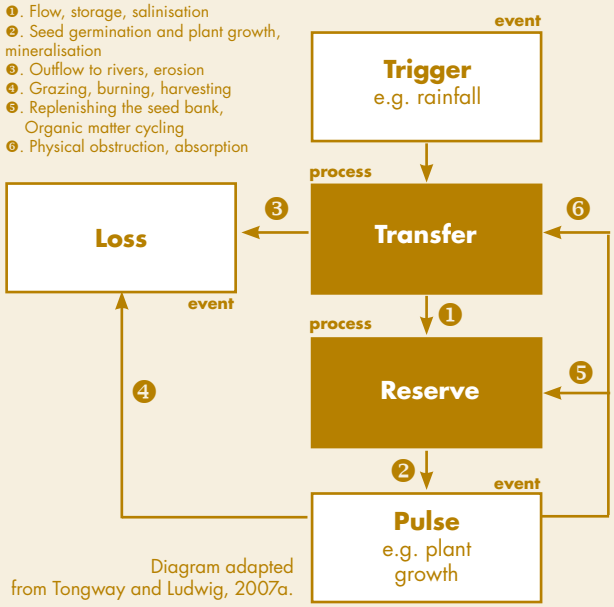


Diagram adapted from Tongway and Ludwig, 2007a.

Other biophysical processes such as the formation of vegetation patches reduce moisture loss and promote its storage after a 'trigger' event ❻.

Source: Tongway and Ludwig, 2007a and b.

Ecological restoration of ecosystem functions in arid and semiarid environments should be focused mainly on restoring water flows, soil fertility and plant cover. Restoration projects associated with desertification control generally involve the reintroduction of plants that are resistant to high salinity, drought and heavy grazing. Several large-scale initiatives have failed, however, because the managers overlooked problems associated with soils and water flows. These managers also often do not take the socioeconomic conditions at the site into sufficient account (e.g. 'green barrier' projects implemented in Algeria in the 1970s, Mainguet and Dumay, 2006). Ecological restoration is a complex process that requires the involvement of many people often with very different views concerning restored ecosystems and sometimes conflicting interests (SER, 2002). Each restoration project should therefore be designed and planned according to the local setting. It is absolutely essential that local people participate in and support RNC projects to ensure their success. Boosting public awareness on the benefits of restoration will help promote such local involvement (SER, 2002).

When setting up RNC projects, it is important to stress the mutual benefits of this restoration for humans and the environment, beginning by defining and communicating concepts pertaining to natural goods and services.

Ecosystem goods and services in arid and semiarid regions

Human populations living in arid and semiarid regions are especially dependent on ecosystem goods and services to fulfil their basic needs. Inhabitants get most of their income by tapping natural resources, with very little coming from the sale of manufactured products. These people are thus highly dependent on natural capital and affected by climate change (Requier-Desjardins, 2007). For instance, cereal, livestock, milk, fuelwood and construction material production depends on plant productivity, which in turn is dependent on water supplies.

Ecosystem services can be ranked in four general categories: ecological process regulation services, goods production services, dwelling/subsistence provision services and cultural information or benefit services.

The following table, from the Millenium Ecosystem Assessment desertification synthesis report (MEA, 2005), provides a list of key natural services in arid and semiarid regions.

The degradation and depletion of natural goods and services has a clear socioeconomic cost for human populations—deterioration of their living conditions. To increase these services, it is necessary to financially evaluate: (1) the impact of their degradation, and (2) the costs and benefits associated with projects implemented for sustainable ecosystem restoration (Requier-Desjardins, 2007; Requier-Desjardins, Bied-Charreton M., 2006). This can be done by measuring the quantity and quality of ecosystem goods and services. Note that the expression 'measuring natural capital stock' is used in this respect to facilitate discussion between ecologists and economists. Background concepts concerning the financial valuation of natural capital are discussed in the following chapter.

Key dryland ecosystem services

Source: MEA, 2005.

Provisioning services	Regulating services	Cultural services
• Provisions derived from biological productivity: food, fiber, forage, fuelwood, and biochemicals • fresh water	• Water purification and regulation • Pollination and seed dispersal • Climate regulation (local through vegetation cover and global through carbon sequestration)	• Recreation and tourism • Cultural identity and diversity • Cultural landscapes and heritage values • Indigenous knowledge systems • Spiritual, aesthetic and inspirational services
Supporting services		
• Soil development (conservation, formation) • Primary production • Nutrient cycling		

Example

Restoring natural capital in tiger bush areas in Australia

A project was carried out from 1996 to 2007 to restore natural capital in semiarid regions of New South Wales, Australia. The main aim was to restore a steady-state productive ecosystem so as to ensure the economic viability of local farms (livestock farming). This required the restoration of grassland functions jointly according to ecological and economic principles.

A natural 'tiger bush' landscape prevails in this region. This type of ecosystem is also found in West Africa and Mexico and landscape consists of bands of vegetation, where strips of woody or grassy zones are separated by bare soil. In this unique landscape structure, resources (especially water) are optimally distributed, so they can be highly productive.

This banded landscape is degraded by livestock trampling and overgrazing, especially close to artificially supplied watering points where herds traverse and graze daily. Tiger bush functional processes thus gradually stall, which then hampers water storage in the soil and promotes environmental desertification. Finally, these rangelands become very unproductive and colonized by low feed value ephemeral plant species that suddenly spring up after occasional rains.

The two following photographs illustrate a functional tiger bush landscape where the natural capital is formed and stored, as well as a degraded landscape in which the natural capital has been lost through soil erosion and plant mortality.

▲ This photo shows a landscape in which much less water is stored in the soil over time. Desertification is under way and all of the trees will ultimately disappear. Grassland areas are dominated by ephemeral species with a low feed value that grow quickly after a rainfall. The ecosystem is completely dysfunctional and the natural capital is eventually lost (through plant mortality or soil erosion).

▲ A landscape with mulga felled by chaining in strips along contours to enhance resource capture and repair damaged country.

A natural capital restoration project was developed in agreement with herd owners with the aim of stopping the desertification process under way. It was based on the TTRP model described in the box on page 15. The project had to be readily applicable, inexpensive and compatible with farmers' practices. The project coordinators thus decided to rehabilitate the basic functions of this ecosystem in a test zone modeled on the ecological and hydrological processes prevailing in the non-degraded zone. The dominant plant in the woody band, i.e. mulga *(Acacia aneura),* was used to recover the physical structure of the ecosystem in a test zone. Mulga branches were piled in bands across the landscape contours in an attempt to capture materials leached by rainfall and blown by the wind. This led to artificial recovery of the woody band. A new perennial plant population began growing on the accumulated captured material. These plants, which were partially protected by the spiny mulga plant structure, were subsequently able to survive despite the usual grazing pressure.

Ten years later, the density of the plant cover and the soil properties were recovered in the test zone. This success in reestablishing the plant cover also meant that the seed pool in the soil was not limited.

Herders sometimes chopped mulga branches in order to reduce competition for soil nutrients between this species and those grazed by livestock. The herders could thus easily tailor their feed storage methods by grazing their livestock on chopped mulga branches in degraded areas. This technique also enhanced pasture production.

This study highlighted that a slight modification in management practices can sometimes be efficient. Simply laying mulga branches in bands across landscape contours was found to be effective in capturing resources and reversing the desertification process. This was economically beneficial for herders while preserving/increasing biodiversity.

Source: Tongway and Ludwig, 2007a and b.

Socioeconomic benefits of restoring natural capital in arid regions

The economic, social and environmental cost of desertification is very hard to evaluate and few studies have focused on this topic (Requier-Desjardins, 2007). The socioeconomic aspects of natural capital restoration in areas affected by desertification are thus generally outlined here, while giving examples illustrating RNC methods that may be applied within the specific framework of desertification control.

Monetary assessment of natural capital and its restoration

Two types of approach can be adopted to determine the economic soundness of degraded ecosystem restoration projects prior to their implementation: (1) assessment of the degradation cost, and (2) assessment of the restoration costs and benefits.

CSFD issue n°5 (Requier-Desjardins, 2007) reviews different desertification macroeconomic cost valuation methods that have been applied to assess situations in Africa. For instance, to valuate the reduction in crop productivity in monetary terms, a cost assessment was conducted in Mali on applying commercial fertilizers to replace lost soil nutrients. This method is only relevant if the natural capital can be replaced by a manufactured substitute, which of course has its limits.

Another method outlined in the Millenium Ecosystem Assessment (MEA, 2003) consists of valuating the cost of desertification as a function of divisions of rural area according to their main economic uses (agriculture, forestry, etc.). This basically involves determining the cost of a loss of natural services in terms of food and fuelwood procurement. These assessment methods are relatively inaccurate because they are based on highly variable reference prices and very simple models, but they are still useful in providing relatively convincing arguments in favour of natural capital restoration.

Approaches resembling those implemented in the Millenium Ecosystem Assessment are used to an increasing extent for assessing ecosystem services from an economic vantage point within the framework of local RNC projects.

Natural capital is still not easy to quantify from a monetary standpoint. Many natural services do not have a 'price', in a figurative sense, since they are essential for life on Earth, or in a literal sense, since they have no economic market value. For reasons that we have already discussed, including nonexclusiveness and nonrivalry, monetary valuation of most natural capital and its restoration is incompatible with conventional economic theories. However, humans have always placed a value on some aspects of nature, including natural services. These 'nonmonetary' values could thus be entrenched in economic market laws (Rees *et al.*, 2007), for instance through the creation of a fictive market **(contingent valuation)**, or by taking the economic cost of pollution into account **(internalization of externalities)** (Requier-Desjardins, 2007).

Millet crop fields in Niger.
P. Blanchon © IRD

Restoring social capital: an essential complement to RCN

To ensure that ecological aspects will be accounted for in economic planning and decision making, i.e. applying economic principles where nature counts (Aronson *et al.*, 2007a), new indicators should be developed to highlight the interdependency between ecosystem health and peoples' quality of life (de Groot, 1992).

According to the RNC approach, social capital is considered to increase concomitantly with natural capital. The aim is to convince local people to accept modifications in natural resource management methods. RNC should preferentially address local demand rather than being a response to national directives.

Measuring the wellbeing of human populations is often erroneously equated with calculating the gross domestic product (GDP). Although GDP is an excellent indicator of the 'size' of a national economy, it is completely irrelevant as a quality of life or wellbeing indicator (Prescott-Allen, 2001).

Focus

Economics and ecosystems: calculating the GDP

GDP is probably the most important economic indicator used by finance ministries worldwide. It represents the total revenue (pay, salary, interest) generated via the production of goods and services in one year. Although it is widely interpreted as being a quality of life indicator, GDP is actually a narrow concept that simply represents a measurement of the total economic activity over a given period. GDP has been substantially criticized by environmental analysts and theorists because it just measures the 'good' but not the 'bad' aspects associated with production, which means that it does not indicate whether the economy is evolving in a sustainable way (Source: de Groot, 1992, quoted from Hamilton, 1990).

Only a few economic indicators are used to measure GDP. These indicators are mainly used to measure manufactured goods and services, whereas natural goods and services are not taken into consideration. Even worse, an increase in quality of life as determined by such indicators often occurs to the detriment of natural goods and services. Environmental degradation should thus be taken into account in national accounting systems, e.g. through GDP deductions. There is not yet any international consensus on this topic despite the work of many specialists (UN, World Bank) over the last two decades.

Source: de Groot, 1992; Marais *et al.*, 2007; Requier-Desjardins, 2007.

Ecosystem degradation is giving rise to ever more serious socioeconomic issues (MEA, 2005), while the relationship between the quality of environmental goods and services and the quality of life of human populations is increasingly evident. Novel systems for calculating peoples' wellbeing based on economic, social and ecological features have been developed. The environmental quality index (de Groot, 1992), as well as the wellbeing index (WI), are new indicators that demonstrate how peoples' quality of life declines with ecosystem quality. In this setting, people recognize that their wellbeing and the future development of their societies are closely dependent on proper ecosystem functioning (Prescott-Allen, 2001).

Example

Quantifying the economic value of natural capital in South Africa

This monetary assessment of the future benefits of a natural capital restoration project was carried out in Bushbuck Ridge (BBR) District, Limpopo Province (South Africa), in 2007. The aim was to determine the economic advantages of a participatory natural capital conservation and restoration project relative to a conventional subsistence farming system. BBR encompasses 235,000 ha, including 184,000 ha of communal land. The 500 000 community members use this land for picking and livestock farming (no cropping or dwellings). Sadly, this communal land is famous for being part of the former 'homelands', i.e. reserves for Black African people under the former apartheid regime. Most of the environmental degradation occurred during that period, when isolated inhabitants were forced to tap natural resources in a nonsustainable way to fulfil their daily needs. The stable democracy that replaced the apartheid regime has prevailed since 1994, but most of the people living in this heavily degraded environment are still poor.

▲ In Limpopo province, most of the environmental degradation is located around rivers (here Klein Letaba River). Such degradation affects the available water quantity and quality, soil fertility and biodiversity.

A restoration project aimed at enhancing the quality of life in the communal area was proposed. The project coordinators suggested that this BBR communal area be incorporated in the adjacent protected Rooibos Bushveld zone of Kruger National Park (KNP). The climatic conditions in these two zones are identical. Moreover, they had the same types of vegetation and animal communities before being totally decimated in the BBR area. KNP is a World Conservation Union (IUCN) Category II protected area where livestock grazing and resource harvesting are not authorized. In contrast, tourism is a highly lucrative activity in the area.

The proposed natural capital restoration project involved merging the BBR communal area with KNP as an IUCN Category VI protected area. Sustainable picking would be authorized, but not livestock grazing. This project is *a priori* supported by local inhabitants. An assessment of the potential economic value (under the proposed restoration conditions) and actual value of directly used natural goods and services from the communal area was carried out on the basis: (1) of the value of the natural capital stock present, (2) of the direct-use value of goods (products derived from sales) and services (tourism), and (3) the indirect-use value of actual environmental goods and services (nutrient recycling in the soil, carbon sequestration) and potential environmental goods and services (or existence value). Only aspect 2 is discussed below (for further information on aspects 1 and 3, see Blignaut and Loxton, 2007).

The value of each resource is estimated according to its harvest rate multiplied by its market sale value. The total potential harvest rate for the entire communal area (if merged with KNP) is restricted by clearcut sustainability conditions. This rate cannot surpass the biomass production rate. The total annual biomass production rate in KNP was estimated to be 3%—edible fruits account for half of this production. The annual potential harvest rate for the BBR zone is thus estimated to range from 0.5 to 1% if the zone is incorporated in the park. The 1% rate is attributed to most products (mainly regularly consumed products and timber), while the 0.5% rate concerns products with more limited marketing options (manufactured and medicinal products).

Natural capital	BBR (Actual)		BBR (Potential)		Difference
	Millions US$	US$/ha	Millions US$	US$/ha	US$/ha
Fuelwood	5.7	31.2	3.5	18.9	-12
Timber	2.7	14.7	4.4	24.0	9
By-products	0.25	1.3	51.2	278.2	277
Medication	4.8	25.6	47.1	255.4	229
Fruit and vegetables	9.3	50.4	1.5	8.2	-42
Thatch	7.0	38.0	0.61	3.2	-35
Livestock	9.4	50.9	0	0	-51
Wild animals	0	0	4.3	23.4	23.4
Total	**39.15**	**212.1**	**112.61**	**611.3**	**398.4**

Currency values are from the 2002/2003 period.

The actual economic value of direct-use harvested resources is estimated to be US$212.1/ha. Income mainly comes from the sale of livestock, fruit and vegetables, thatch and fuelwood. The potential economic value of direct-use harvested resources is estimated to be US$611.3/ha. The highest proportion of revenue comes from the sale of high added value medicinal and manufactured products. Note that these economic values are estimates. An alternative scenario, where the potential estimated values are divided by 2, is thus also proposed. This gives an economic return rate of US$305.65/ha, to which the tourism potential of the communal area after its potential merger with KNP can be added. The economic value of tourism in the Rooibos Bushveld zone is estimated at US$98/ha, whereas it is currently nil in the BBR communal area.

The estimates showed that the actual economic value of the BBR zone is US$212.1/ha, whereas its absolute minimum potential economic value is US$305.65/ha. This value is underestimated since it does not take the added tourism value or aspects 1 and 3 of the previously discussed assessment into account. When all of these aspects are considered, the total estimated economic value is US$837.48/ha (and US$491.32/ha for a minimum alternative scenario).

This study revealed that the type of use proposed for the BBR communal area has a higher potential economic value than its actual value. The study was based on the assumption that the zone could be merged with KNP, without any change of owners and with an authorization for a sustainable natural resource harvesting rate. BBR inhabitants favoured incorporation of the area into the park, so the findings of this monetary assessment could eventually be of use when the project is actually launched

Source: Blignaut and Loxton, 2007.

Flower of the Proteaceae family. South Africa
C. Lévêque © IRD

How does environmental degradation affect human populations? And how can natural capital restoration lead to an improvement in social wellbeing? Restoring degraded ecosystems in poor countries can only benefit from local support if the initiative provides clear answers to these questions (Aronson *et al.*, 2006b; Aronson *et al.*, 1993).

The interdependency between the quality of life and ecosystem quality is gradually being put forward on national and international levels through studies like that presented in the box on page 23 (case study in Tunisia), and the development of new wellbeing indices. On the local level, target RNC projects can help to effectively reestablish healthy respectful relationships between humans and their environment.

Focus

Calculation of the wellbeing index: an example in Mali

The wellbeing index (WI) of Prescott-Allen incorporates two components: an index of the wellbeing of human populations *sensu stricto* (the human wellbeing index; HWI) and an index of ecosystem wellbeing (the ecosystem wellbeing index; EWI).

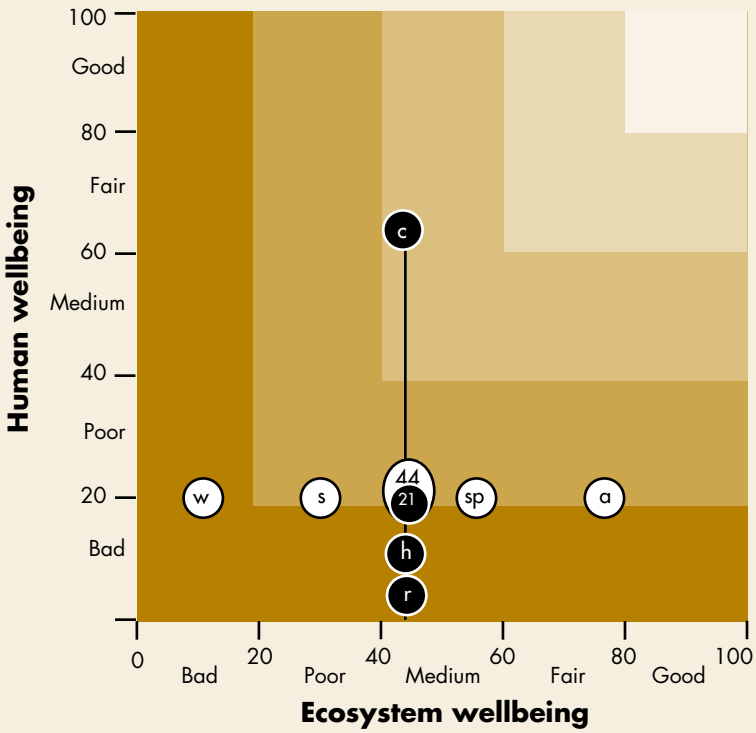
The HWI is calculated on the basis of a set of data grouped according to four themes: community, equity, health, and know-how.

The EWI is calculated on the basis of a set of data grouped according to five themes: air, land, natural resource use, species and genes, and water.

The WI structure for Mali is illustrated below. The WI is located at the interface of the dark brown zone (bad) and the light brown zone (poor). On the vertical axis in this figure, the community 'circle' (c) raises the HWI level. This is due to the fact that there has been a stable democracy with well established freedom of speech since the 1990s. The human rights data are positive overall, but this trend should be moderated in the light of the occasional violent clashes between communities and police brutality (even torture). Figures concerning other dimensions are rather low and drag the HWI downward. This is due to the poor sanitary conditions, acute malnutrition, very high infant mortality and low scolarization rates.

On the horizontal axis, the quality of life in Mali is impeded by the poor soils and water quality (on the far left in this figure). Indeed, the rivers and groundwater are highly polluted and 40% of the cultivated land is moderately to highly degraded.

Source: Prescott-Allen, 2001.



Wellbeing structure in Mali

Black circles represent human dimensions.
c = community, e = equity, h = health and population, k = knowledge, r = richness.

White circles represent ecosystem dimensions.
a = air, s = soil, u = resource use, sp = species and genes, w = water.

One dimension is positioned behind another one (knowledge behind richness).
The Malian HWI excludes equity and its EWI excludes resource use since both of these dimensions would artificially boost these two indices.

Example

Degradation of the environment and human wellbeing in Tunisia

A case study carried out in Tunisia revealed how environmental degradation can lead to a decline in national human wellbeing, thus indicating that this loss should be included in environmental degradation cost assessments. The loss of national human wellbeing is expressed here in three forms, with each type of loss then being calculated according to a certain number of indicators:

1. loss of a healthy living environment (via early death, serious health problems, poor hygiene and lack of a clean environment, etc.);
2. economic loss (reduction in farmland productivity, loss of tourism income, etc.);
3. loss of environmental opportunity (loss of recreational functions of a lake, beach, forest, etc.).

The measurement of these different losses is included in the degradation cost assessment. The aim of this type of study is to highlight the interdependency between the ecosystem health in a country and the quality of life of its inhabitants. On a national scale, the aim is to foster the drawing up and implementation of government legislation and directives that will promote sustainable resource use, and restoration where necessary.

Source: Sarraf *et al.*, 2004.

A seller's stand in a market, Médenine, Tunisia.
V. Simonneaux © IRD

Do arid regions warrant RNC investment?

Restoring the natural capital of a site hinges on a delicate balance between many ecological and socioeconomic factors. The prime goal should be to maximize the socioeconomic and environmental benefits within the framework of sustainable development. Some RNC areas require further attention, especially in developing methods to evaluate the success of restoration projects and clarifying the potential funding mechanisms for these projects.

Evaluating the success of restoration projects

According to the Society for Ecological Restoration International (SER, 2002), the restoration objectives and strategy to be adopted will closely depend on the type of degradation, the government's attitude, local peoples' expectations and the biophysical constraints at the degraded site.

The success of a restoration project depends on how well targeted the project objectives are in addressing the socioeconomic expectations of local people. Just assessing the 'ecological' success of the project is therefore not enough to determine whether the restoration achievements will be sustainable in the long run. The success of a restoration project also depends on its economic and social development potential (Cairns, 2000; Geist and Galatowitsch, 1999; Higgs, 1997).

Assessing the long-term success of restoration projects is important for: (1) improving ongoing projects, and (2) assisting in setting up future projects (Atkinson, 1994). Clearly demonstrating that the initial objectives of a restoration project have been fulfilled can also be useful in clinching the support of investors and local people with respect to setting up new projects (Hobbs and Harris, 2001).

RNC project managers are, however, often hampered by the uncertain and unpredictable aspect of restoration processes implemented (due to the nature of ecological processes), and by the need to promote the often intangible benefits of restoration. This makes it hard to justify investment in RNC projects and to assess their short-term success.

Multicriteria assessment techniques are gradually being developed to provide RNC investment assistance and substantiation. In multicriteria analysis methods, the best available strategy is selected to achieve a set of predefined objectives. The RNC motives and benefits should thus be clearly delineated at the beginning of projects.

Multicriteria analysis is a three-step process, including (Rees *et al.*, 2007):

1. working with the different stakeholders to define: (a) the project or programme targets, (b) the different success criteria, and (c) the importance (weights) of the different evaluation criteria;
2. deciding on the different strategies required to achieve the objectives, evaluating how each strategy addresses the preset success criteria, and selecting the best strategies;
3. classifying the different options and facilitating implementation of the final strategy.

Note that external factors, such as changes in the values expressed by the community, new information or political pressure, can have a positive or negative impact on the evolution of an RNC project (Young *et al.*, 2007).

In parallel, baseline restoration project costs are generally high, while the benefits increase later (Aronson *et al.*, 2007a; Holl and Howarth, 2000; Requier-Desjardins, 2007). Local restoration initiatives should thus be combined with public and private investment.

Hiring job seekers from local communities is one aim of the 'Working for Woodland' programme in Limpopo province, South Africa. People are actively recruited and trained to perform specialized duties such as constructing fences to protect restoration project sites, implementing erosion control and soil enrichment measures, removing invasive species, collecting and sowing seeds of indigenous plants, and propagating selected tree species for planting.

Restoration funding

Restoration funding mechanisms generally fall into two categories, i.e. mechanisms based on the 'impacter pays' concept and those based on the 'beneficiary pays' concept. The costs are sometimes shared between the two categories. The ultimate decision is political and depends on the different expectations of each community involved and the prevailing economic powers.

The recovery capacity of a degraded ecosystem depends on the type, extent and frequency of the impacts to which it has been subjected (SER, 2002). In arid and semiarid environments, the soilborne seed availability, soil structure and fertility and water flows can be highly affected.

Under extreme temperature, grazing and low humidity conditions, etc., it takes a very long time for plants to germinate and develop, even when there are no disturbances. There is very little chance that a degraded ecosystem will be able to recover without human intervention, even if grazing and all other types of disturbance have been curbed (Bainbridge, 2007).

Even the most costly restoration activities are quite necessary. Land degradation in arid and semiarid environments is a problem that is not limited to poor countries but, as discussed earlier, poor living conditions can substantially spur the process. Desertification has an ecological and economic impact in many countries, including the richest ones. It is therefore essential to set up information systems and draw up legislation in both developing and developed countries to sidestep this type of extreme situation.

▲ Desertification caused by overgrazing in Chihuahua, Mexico. With this extent of environmental degradation, very few goods can be produced unless restoration measures are implemented.

Example

Participative and adaptive restoration management for communal areas in South Africa

Inhabitants of communal areas in South Africa are highly dependent on natural resources. For instance, land degradation can lead to a sharp decrease in the size of livestock herds and fuelwood, medicinal plant and timber availability. In Pikoli village (Peddie District), the density of two *Acaria karoo* preferred fuelwood varieties was reported to decrease linearly with distance from the village. Hence, women, who have the role of collecting wood, must walk long distances and find it difficult to find sufficient quantities. Moreover, inhabitants of Macubeni (Eastern Cape) can no longer find enough medicinal plants to treat their livestock.

These examples generally illustrate how food (and water) availability in South African rural communal areas is declining to an increasing extent due to environmental degradation. This degradation of communal land is also associated with larger scale socioeconomic problems such as high outmigration and loss of self-esteem, local identity and traditional ecological know-how. These different combined negative effects upset social cohesion and prompt local institutions to lose interest and governments to reduce their support.

Natural capital restoration of these areas has been proposed as a means to reduce social issues associated with land degradation. However, local inhabitants' insecure situation hampers the development of individual initiatives. The community and governmental (and potentially nongovernmental) institutions should thus codevelop a restoration strategy.

Local communities should first realise that the scarcity of natural resources is due to: (1) overtapping of resources by local people, (2) the reduced capacity of the government to provide technical assistance, and (3) climate change. Moreover, the restoration strategy should be focused on (1) the capacity of ecosystems to supply goods and services (resources, productivity), and (2) their resilience with respect to climate change.

A 10-step method was developed for participative and adaptive restoration management for communal areas in South Africa, but the underlying concepts are widely applicable.

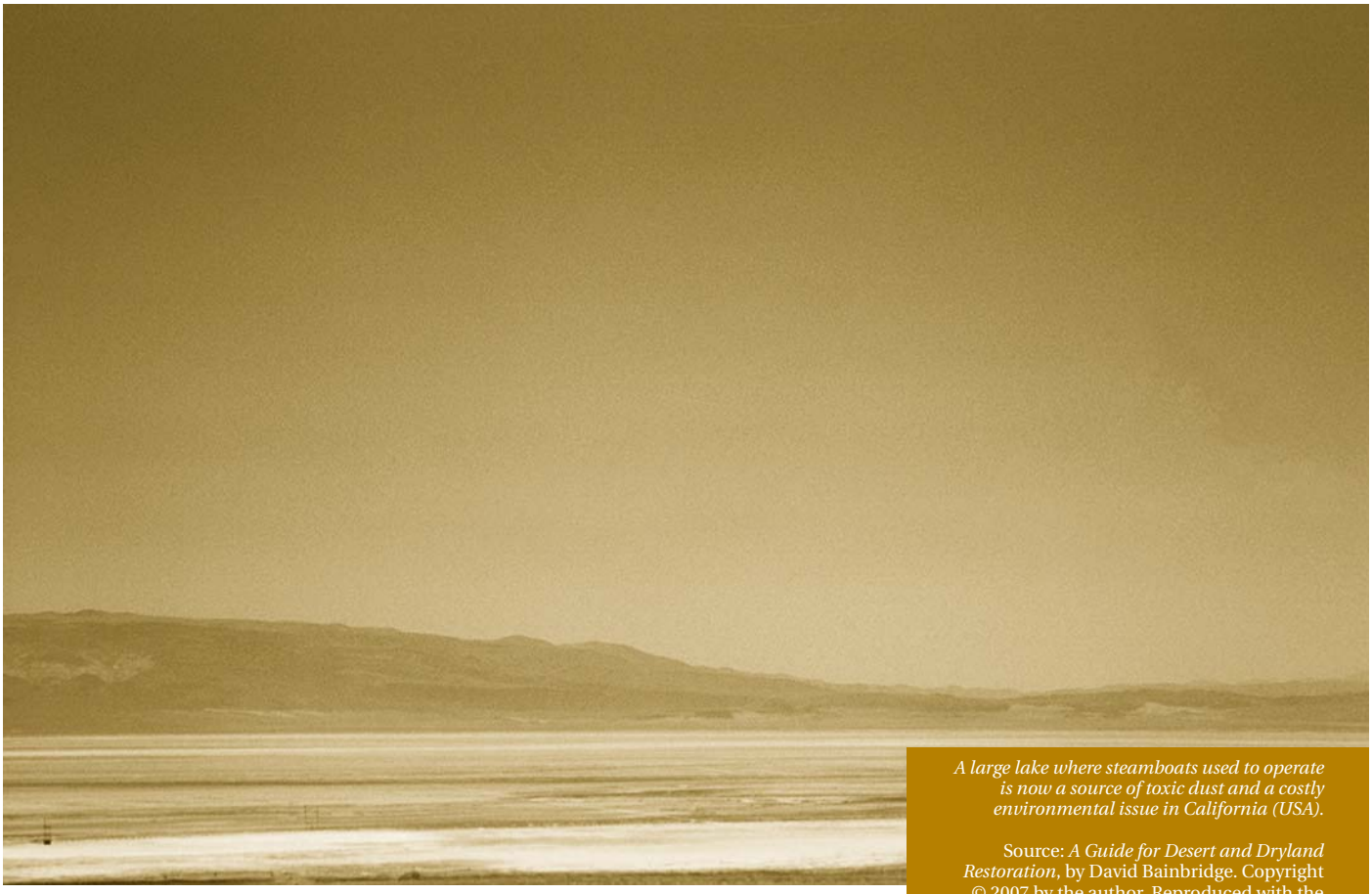
1. Conceptualize an integrated model of the ecological and socioeconomic system to be restored.
2. Combine formal (remote sensing) and informal (conventional) sources of knowledge and information.
3. Identify different project stakeholders and mainstream them into the decision-making process.
4. Agree on a clear and shared vision of the restored system.
5. Agree on a clear and shared vision of future restoration benefits (often indirect and long term).
6. Identify the role of key individuals responsible for setting up and monitoring the project.
7. Foster flexibility and diversity of opinion between project coordinators in order to increase the resilience of the project and reduce its vulnerability.
8. Develop national governmental or municipal facilitation and professional training systems.
9. Develop professional skills for simultaneously handling economic, sociopolitical and ecological processes involved.
10. Accept the uncertainties and benefits associated with adaptive management ('learning by doing').

The two following examples show how rural communities and other institutions could combine forces to restore natural capital.

At Macubeni (Eastern Cape), local communities have recently mobilized themselves around a vision of sustainable natural resource use and ecosystem restoration. They expressed their vision as follows: "*A better life for all, by managing our natural and manmade resources sustainably, in order to improve our livelihoods, health, education, and economy, while still maintaining our traditional culture and values, so that there will be a brighter future for the people of Macubeni*". A steering committee was formed to oversee the development of a long-term land use plan. Local people are currently setting up a project to restore the severely degraded watershed around the Macubeni dam. This project benefited from the assistance of several municipalities and local government departments concerned with agricultural, environmental, health, and economic issues. In conjunction, a university research programme is involved in fund-raising, facilitation, technical support and development assistance.

On the Wild Coast (Eastern Cape), community action has led to the formation of a community tourism organization, a community-based conservation plan, and a partnership with the private sector. In collaboration with a communal association (Nqabarha Development Trust), inhabitants set up three institutions: a forest management committee, a craft production committee, and a medicinal plant user's group that falls under the umbrella of the Trust. They have developed a land management plan, formulated regulations to strengthen the participative management laws, and developed strategies for income generation, fund-raising and field training. They also established a vegetable and medicinal plant nursery and a craft workshop. In addition, plans are underway to develop certain tourism opportunities with private investors. The local municipality, Rhodes University, the national government and the German agency for technical cooperation (GTZ), support their work.

Source: Fabricius and Cundill, 2007.



A large lake where steamboats used to operate is now a source of toxic dust and a costly environmental issue in California (USA).

Source: *A Guide for Desert and Dryland Restoration*, by David Bainbridge. Copyright © 2007 by the author. Reproduced with the permission of Island Press, Washington, DC, USA.

RNC projects generally require joint public (through national taxes and duties) and private funding. Private partners are identified according to the local project beneficiaries. Various types of project participation are possible, such as participation in field management activities or equipment funding/sponsoring.

▲Heavy grazing pressure can quickly lead to the disappearance of all vegetation cover. When looking at this bare rock landscape, it is hard to imagine that trees, bushes, flowers and grasses were previously growing on the same site. This area was laid bare within just a few years. South-western USA.

Source: *A Guide for Desert and Dryland Restoration*, by David Bainbridge. Copyright © 2007 by the author. Reproduced with the permission of Island Press, Washington, DC, USA.

Funding is not the only factor limiting the implementation of RNC projects. Restoration activities are still uncommon and few people have the knowledge and experience necessary to perceive what a restored ecosystem could be like. Indeed, it is hard for most people to imagine how a degraded area could appear after restoration. Mainstreaming local stakeholders into accountability and empowerment aspects of RNC projects is an effective way to promote restoration and modify human behaviours with respect to Nature (Leigh, 2005).

▲Closeup photos of a highly degraded site in Argentina (Sierras de Cordoba), just before (1997, left photo) and after (2006, right photo) the launching of a restoration project.

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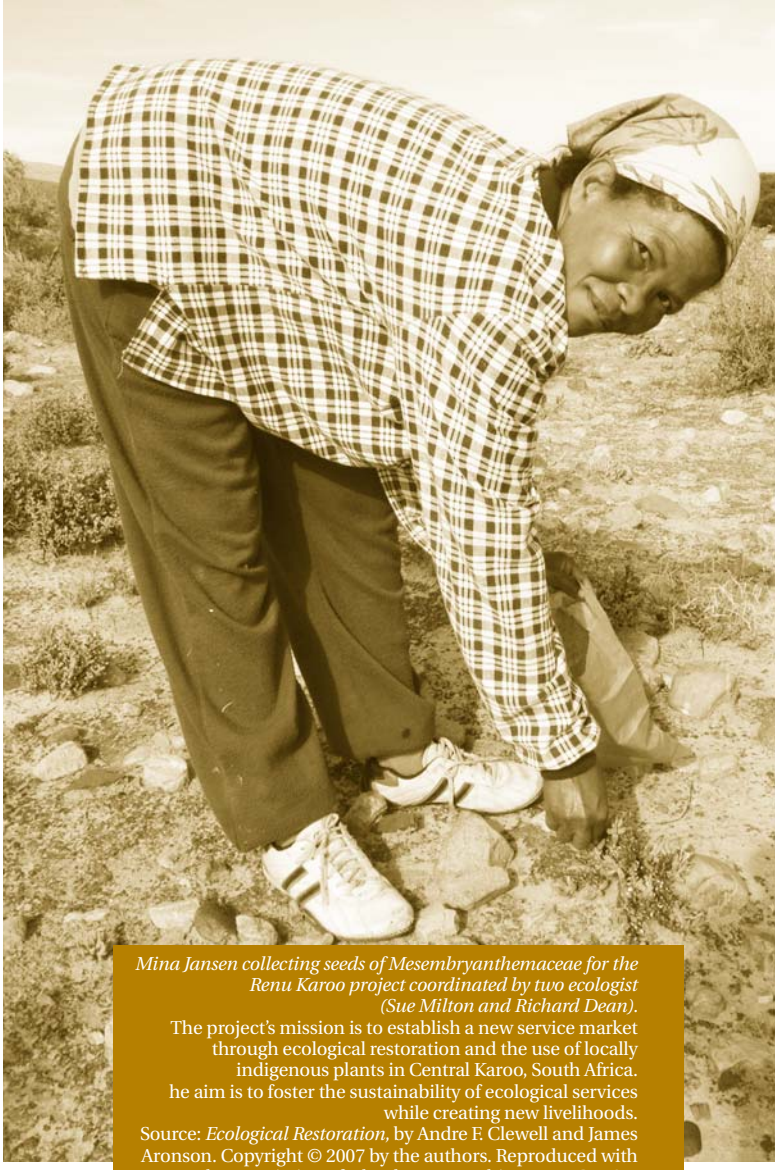
Prospects: towards a sustainable relationship between humankind and the environment?

Ecosystem dynamics, including desertification processes, include a high social contribution—humans are part of the ecosystem, influence their dynamics and, in return, incur the positive or negative consequences (INSU/CNRS, 2004). In addition to being production systems, ecosystems are the source of natural services essential for human societies.

The cost and complexity of restoring these services increase as the natural capital declines, so it is obviously more advantageous to invest in sustainable exploitation methods than to restore what has been degraded. While awaiting an effective sustainable resource management policy to be drawn up, the RNC approach—which meshes natural capital restoration with social capital restoration—fosters the benefits of a sustainable relationship between humans and their environment. This can be summed up in a key statement: the wellbeing of human populations depends on ecosystem health and the quality of the resulting natural services.

Ecological and social problems associated with land degradation in arid and semiarid environments can no longer be overlooked by international (through development aid) and national policymakers. Desertification processes are destabilizing societies to an increasing extent on local levels by exacerbating poverty, and on national levels by creating environmental refugees.

This degradation is not, however, inevitable. We have seen in this document that mechanisms can be set up to ensure simultaneous restoration of natural and social capital in arid regions. Local peoples' values, needs and aims should obviously be mainstreamed into policymaking processes. However, no efficient legislation has been passed to date—this failure leaves the way open to continued implementation of management strategies that are detrimental to the environment and social capital (Adeel *et al.*, 2006). The protection, restoration and sustainable management of the five types of capital (financial, manufactured, social, human and natural), as well as the strengthening of social and institutional networks (that promote fair access to these different capitals) should be embedded in management plans.



Mina Jansen collecting seeds of Mesembryanthemaceae for the Renu Karoo project coordinated by two ecologist (Sue Milton and Richard Dean).
The project's mission is to establish a new service market through ecological restoration and the use of locally indigenous plants in Central Karoo, South Africa. he aim is to foster the sustainability of ecological services while creating new livelihoods.
Source: *Ecological Restoration*, by Andre F. Clewell and James Aronson. Copyright © 2007 by the authors. Reproduced with the permission of Island Press, Washington, DC, USA.

Sustainable management planning is not anti-technology or anti-business. The link between degraded ecosystem restoration and human quality of life should be further promoted in policies through positive educational, communications and technical assistance subsidies, etc.

How could decision-makers be persuaded to get involved in natural, social and human capital restoration?

It is clear from the overall discussion presented in this special issue that arguments must be found that could persuade public authorities and private investors to invest in restoration. Three argument orientations could be considered:

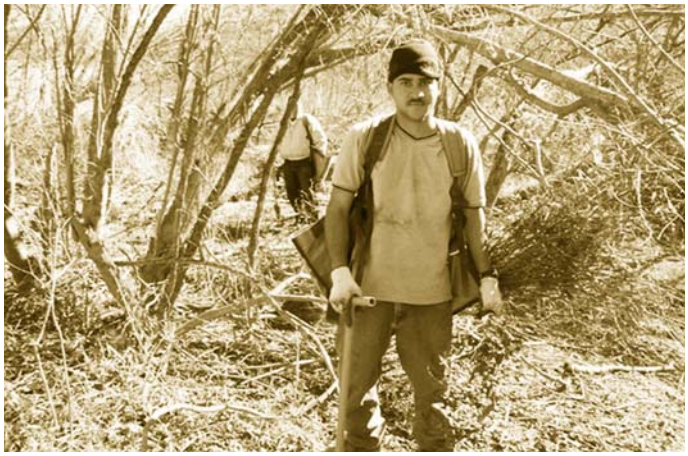
■ ***Natural capital oriented arguments:*** So far it has been hard to persuade funding agencies that it is important to restore soils, vegetation and generally

natural capital, while also improving management of water and natural resources and ecosystems overall. There have not yet been enough cost-benefit analyses focused on resource management, agriculture and livestock farming enhancement or water management improvement initiatives in arid and semiarid countries, and most of the ones that have been conducted were focused solely on agricultural and livestock farming issues. Some projects to combat desertification have thus been analysed in recent years (Reij and Steeds, 2003; Hien *et al.,* 2004; Requier-Desjardins and Bied-Charreton, 2006). The findings of these projects are very interesting but not yet widely acknowledged. A highly positive investment return rate (10-30%) has been noted, sometimes with a lag time of several years before this rate is reached. We should gain further insight into these issues in 2008 through ongoing initiatives funded by the World Bank (TerrAfrica initiative), the French Development Agency (AFD) and the French Global Environment Facility (FGEF). These initiatives are associated with an international network on the costs of inaction that was set up recently following an international workshop on the costs of inaction and investment opportunities in arid, semiarid and subhumid dry areas held in Rome (Italy) in December 2006 (Requier-Desjardins, 2007).

■ ***Peoples' wellbeing oriented arguments:*** Here politicians are more concerned because the negative effects of resource and ecosystem degradation are more immediately obvious: decreased yields and revenue, increased poverty, social destabilization and outmigration. However, the remedies and initiatives to rectify this income loss problem are not very clearcut; national and international public investment in rural areas has been declining for 20 years. With respect to official development assistance (ODA), the proportion of investment in land management (including agriculture and livestock production) dropped in 20 years from around 20% to 5% in 2006 ($5 billion out of $100 billion in global ODA). Some specialists even wonder whether it would be better to target assistance to urban areas or other sectors rather than to rural areas. Outmigration, especially international outmigration, has been an ongoing trend for a long time—it is an embarrassing situation without any clear solution for the moment. Governments and public development assistance decision makers are already aware of the importance of preserving human capital by supporting education and health, and of social capital by supporting civil society and recognizing the quality of village organizations which, in many countries, have become legal associations authorized to enter into contractual liability actions.

■ ***Global environment oriented arguments:*** These are based on the concept that ecosystems provide services and that healthy local environments contribute to the health of the global environment—but these arguments are still in the budding phase. The increased risks that have arisen as a result of climate change, and the increased vulnerability of societies that depend almost solely on ecosystems to fulfil their needs, have tended to consolidate this set of arguments. These now encompass questions of adaptation, as considered during the recent UN Climate Change Conference (Bali, December 2007). Within the framework of the Kyoto Protocol, the focus was placed only on adaptation in developed societies, including greenhouse gas emission reduction, technologies and economic mechanisms. This has somewhat shrouded the issue of preserving natural capital. It now seems, however, that the measures considered in the follow-up to the Kyoto Protocol will pave the way to fostering the crucial role of natural capital and the importance of preserving and restoring it.

The scientific community now has a key role to play in explaining the natural capital restoration challenges on the basis of confirmed scientific arguments. This will be our contribution to combating poverty and preserving the quality of local and global environments.



▲A forest restoration project under way in the Pascagoula River flood zone, (Mississippi, USA), which was set up to accelerate the recovery of the vegetation cover following the damage caused by Hurricane Katrina in 2005.

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For further information...

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Agriculture in Niger. Eroded soil cultivated with millet. Niger. A. Luxereau © IRD

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Children in the San region of Mali.
M. Dukhan © IRD

Inner Niger Delta region. A young Fula herder bringing his herd back into the Delta to graze the wetland pastures. Danngeere Saya, Mali.
O. Barrière © IRD

List of acronyms and abbreviations

- AFD: *Agence Française de Développement* / French Development Agency
- BBR: Bushbuckridge, South Africa
- C3ED: *Centre d'économie et d'éthique pour l'environnement et le développement* / Center for Economics and Ethics of the Environment and Development, France
- CEFE: *Centre d'Écologie Fonctionnelle et Évolutive* / Center for Evolutionary and Functional Ecology, France
- CNRS: *Centre National de la Recherche Scientifique* / French Scientific Research Center
- CSFD: *Comité Scientifique Français de la Désertification* / French Scientific Committee on Desertification
- CSIRO: Commonwealth Scientific and Industrial Research Organisation, Australia
- EWI: Ecosystem wellbeing index
- FGEF: French Global Environment Facility / *Fond français pour l'environnement mondial (FFEM)*
- GDP: Gross domestic product
- GPG: Global public goods
- GTZ: *Deutsche Gesellschaft für Technische Zusammenarbeit* / German Agency for Technical Cooperation
- HWI: Human wellbeing index
- IRD: *Institut de recherche pour le développement,* France
- IUCN: International Union for Conservation of Nature, Switzerland
- KNP: Kruger National Park, South Africa
- MEA: Millenium Ecosystem Assessment
- ODA: Official Development Assistance
- RNC: Restoration of natural capital
- SER: Society for Ecological Restoration International, USA
- SLED: Sustainable livelihood enhancement and development
- TTRP: Trigger-Transfer-Reserve-Pulse model
- UMR: *Unité mixte de recherche* / Joint research unit
- UN: United Nations
- USA: United States of America
- UVSQ: *Université de Versailles Saint-Quentin-en-Yvelines* / University of Versailles Saint-Quentin-en-Yvelines, France
- WI: Wellbeing index
- WWF: Global environmental conservation organization

Glossary

Biodiversity: The diversity and interactions of life at different organization levels (genome, individual, population, community, ecosystem, bioregion, biosphere) and taxonomic levels (species, genus, family).

Contingent valuation: A hypothetical estimate of the price of unmarketable goods and services based on the findings of questionnaires asking respondents how much they would be willing to pay for a supplementary unit of goods, or how much compensation they would be willing to accept for a loss of specific goods.

Ecological restoration: Defined by the Society for Ecological Restoration International (SER, 2002) as *"the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed, often as the result of human activities".*

Economic development: An increase in quality of life at a specified fixed production rate (Daly and Farley, 2004).

Economic globalization: The elimination of national boundaries for the purposes of economic trade (Daly and Farley, 2004).

Ecosystem: A complex of living organisms and their environment with which they interact at a specified location.

Ecosystem functionality: The vital dynamics of natural processes within an ecosystem.

Ecosystem health: In reference to the definition provided by Costanza, Norton and Haskell (1992), the general term 'health' is used to illustrate both the sought-after state of a restored ecosystem and the underlying restoration guidelines. The health of an ecosystem partially depends on its resilience capacity, extent of organization (composition, structure, connectivity) and vitality (functionality, productivity).

Internalization of externalities: In natural environment management, externalities are unexpected and uncompensated side effects of human activities on ecosystems. These externalities are internalized by taking the environmental damage and benefits of a human activity into account when assessing the costs and benefits of this activity.

Natural capital: An economic metaphor representing the stock of functional ecosystems, including biodiversity, that ensure the flow of goods and services upon which human economy and wellbeing are based (Aronson *et al.*, 2007 a and b).

Natural (or ecosystem) goods and services: Include, for example, food, fibre and fuelwood (goods); providing clean water, crop pollination, climate maintenance (carbon sequestration) and fulfillment of human cultural, spiritual and intellectual needs (services).

Resilience: Capacity of an ecosystem to persist on a given trajectory when encountering natural or human disturbances (Aronson *et al.*, 2007b; Westman, 1978).

Restoration of natural capital (RNC): Replenishment of natural capital stocks in the interests of long-term human wellbeing and ecosystem health (Aronson *et al.*, 2007a and b).

Return-on-investment: A direct economic return that benefits local communities (restoration stakeholders) (Daly and Farley, 2004).

Sustainable local economic development (SLED): Sustainable development is defined as "*providing for the needs of the current generation without compromising the ability of future generations to provide for their own needs*" (Brundtland Report, from the World Commission of Environment and Development, 1987). In this context, 'sustainable' refers to an offtake rate. In sustainability conditions, the harvest rate is lower than the growth (or renewal) rate of the tapped resource (Daly and Farley, 2004). Sustainable livelihood enhancement and development (SLED) terms are increasingly used to define sustainable development on a local scale, while stressing its immediate tangible implementation.

Abstract

The overall aim of this CSFD thematic report is to communicate, share and discuss key elements of restoring natural capital in arid and semiarid regions. Its main goal is to promote the implementation of this approach within societies and communities that are the most threatened by desertification.

The regions threatened by desertification cover about 40% of the emerged land masses. Most people living in these regions are exposed to poverty or extreme poverty. An approach to simultaneously restore degraded ecosystems and improve human wellbeing is urgently needed.

Biodiversity conservation, poverty alleviation and economic development are traditionally perceived as having separate or even conflictual interests. This report shows the contrary. Indeed, restoring natural capital combines ecological restoration and sustainable development objectives in order to create a synergy between them both and also the maintaining of native biodiversity.

Several sites throughout the world in arid or semiarid areas are discussed to illustrate elementary concepts of natural capital restoration in the field. This report is the result of the literature review of the available scientific material relevant to natural capital restoration in arid and semiarid areas. Most of the definitions and field illustrations are adapted from Aronson, Milton and Blignaut (2007), a book written by 71 international scientists, managers and journalists in the fields of ecology, economics and ecological economics.

Key words: Natural capital, ecosystem services, restoration, sustainable development, social capital, desertification

Résumé

Ce dossier thématique du CSFD se situe dans le cadre d'une volonté de communication, de partage et de discussion des éléments clés de la restauration du capital naturel en zones arides et semi-arides. Son but principal est de promouvoir l'insertion de cette approche au sein des sociétés et des communautés les plus touchées par les processus de désertification.

Les régions menacées par la désertification couvrent environ 40 pour cent des terres disponibles. Elles sont le plus souvent le lieu de pauvreté extrême. Une approche visant à restaurer simultanément les écosystèmes et la qualité de vie des populations locales y est par conséquent nécessaire.

La conservation de la biodiversité, la lutte contre la pauvreté ou le développement économique sont communément perçus comme ayant des intérêts indépendants et souvent conflictuels. Ce dossier nous montre que la restauration du capital naturel vise à mettre en commun ces intérêts à priori différents. En effet, cette approche associe restauration écologique et développement durable afin de mettre en synergie les bénéfices respectifs de ces deux approches.

Plusieurs sites variés à travers le monde, situés en zones arides ou semi-arides, ont été choisis pour illustrer les concepts élémentaires de la restauration du capital naturel sur le terrain. Ce dossier est le résultat d'une compilation bibliographique effectuée à partir du matériel scientifique disponible relatif à la restauration du capital naturel en zones arides et semi-arides. La grande majorité des définitions et des illustrations pratiques est adaptée de Aronson, Milton et Blignaut (2007). Un ouvrage regroupant 71 scientifiques, gestionnaires et journalistes de la communauté internationale dans les domaines de l'écologie, l'économie, et de l'économie écologique.

Mots clés : *Capital naturel, services des écosystèmes, restauration, développement durable, capital social, désertification*

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Landscape: Irrigation in an arid environment, Tunisia – J. Pouget © IRD
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