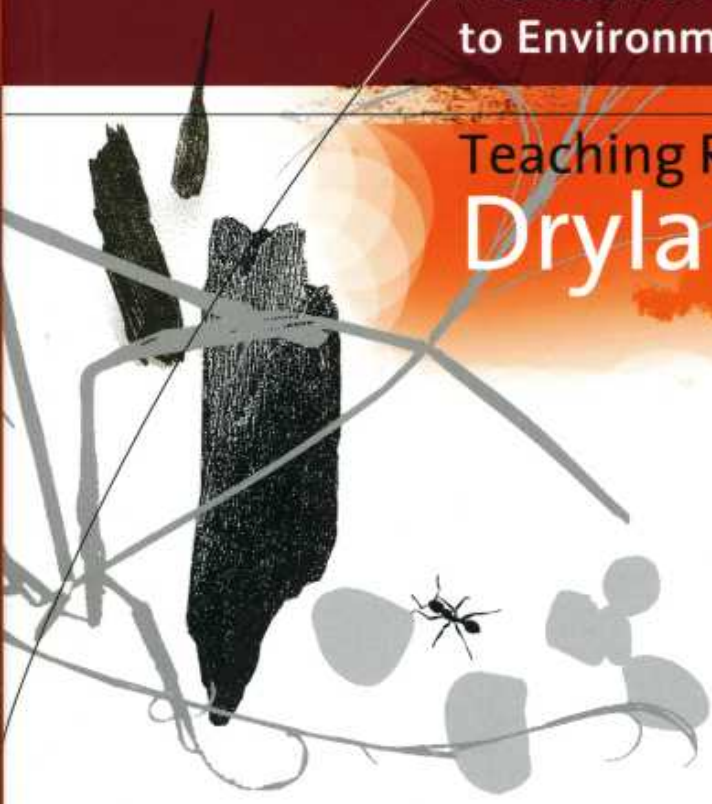
Teacher's Manual

A Creative Approach
to Environmental Education

Teaching Resource Kit for Dryland Countries



United Nations
Educational, Scientific and
Cultural Organization

Man and the Biosphere
Programme

UNESCO
Associated Schools

Teaching Resource Kit for Dryland Countries

A Creative Approach to Environmental Education

"Nature may be interpreted in various ways – as a basis for scientific business endeavours; as a resource; something to look at, experience and enjoy; or as an artistic inspiration."

President Nelson Mandela, October 1994

Officer-in-charge:
Thomas Schaaf, UNESCO

Editor and project designer:
Hélène Gille

Scientific advisers:
Michel Le Berre, Thomas Schaaf

Coordination and iconography:
Hélène Gille
With the collaboration of:
Cathy Lee

Translation:
Dick Nowell, Paul Green

Graphic design:
Mecano, Laurent Batard
assisted by Mélanie Freynick
and Marion Malpeyrat

Administrative assistance:
Natasha Lazic

Photoengraving:
Num Créative

Printing:
LM Graphie

Printed on Galaxy white super matt coated paper
150 g and 350 g

Cover photograph:
View of *El Ateuf, M'Zab Valley*, Algeria, 2002
©Olivier Brestin

Published in 2008 by
the Man and the Biosphere Programme (MAB), UNESCO
1, rue Miollis
75732 Paris Cedex 15, France
E-mail : mab@unesco.org
www.unesco.org/mab

Preface

This environmental education kit for dryland countries was developed on the initiative of the Man and the Biosphere Programme (MAB) of the United Nations Educational, Scientific and Cultural Organization (UNESCO).

As a follow-up to the *Education Kit on Combating Desertification* aimed at primary-school teachers and launched in 2001, UNESCO decided to develop this new educational tool to provide specific and practical aids for teachers and pupils to help them gain a better understanding of their region's environmental problems and thus encourage them to seek possible solutions.

Entitled *A Creative Approach to Environmental Education/Teaching Resource Kit for Dryland Countries*, the kit is intended for secondary-school teachers in countries affected by desertification and is based on an innovative approach appealing to the creativity and artistic sensibility of pupils aged 10 to 15 years. This approach favours discovery of the environment through the senses, and emphasizes the visual and exploratory aspects of environmental study. The idea of using creativity and artistic sensibility to promote ecological awareness may in the future become a source of collaboration to be explored in detail by the different sectors of UNESCO.

The content of the kit echoes the United Nations General Assembly's resolution proclaiming 2006 as the International Year of Deserts and Desertification, it is also consistent with the activities developed as part of the United Nations Decade of Education for Sustainable Development (2005–2014), the promotion of which falls within UNESCO's fields of competence.

The kit is being distributed by UNESCO's Associated Schools Project Network (ASPnet) comprising a total of 8,000 schools in 177 countries, and benefits from the support of the United Nations Decade of Education for Sustainable Development through activities organized in the various countries involved.

We invite teachers interested in the kit or requiring information about how to use it to contact UNESCO's regional offices in their respective countries and refer to the Internet and email addresses of the project organizers: **www.unesco.org/mab** and **mab@unesco.org** and to the web sites of partner programmes at UNESCO in the field of education: the UNESCO Associated Schools Project Network (**www.unesco.org/education/asp**), and the Decade of Education for Sustainable Development (**www.unesco.org/education/desd**).

We would like to extend our warmest thanks to the Flemish Government of Belgium for their financial contribution to the entire development process of this teaching resource kit as part of its broad support for the Natural Sciences Sector, demonstrating that environmental education is as much a part of science as it is of education.

Natarajan Ishwaran
Director, Division of Ecological and Earth Sciences
Secretary, Man and the Biosphere (MAB) Programme

Table of contents

Introduction

The objectives of the kit

In dryland ecosystems, all sectors of the population are affected by desertification and erosion problems that result in environmental degradation and affect their ability to live in a challenging natural environment.

Environmental education and awareness are vital and must begin early if they are to have an impact on the individual. With a view to giving secondary-school pupils (and older primary-school pupils) a better understanding of dryland ecosystems, this teaching resource kit offers a creative approach to environmental education designed to arouse pupils' curiosity, capture their attention and help improve the transmission of scientific information and environmental knowledge.

The primary objective of the kit is to help teachers transmit the scientific and ecological information contained in it in an entertaining and appealing way.

The longer term objective is to develop the ability of pupils and the community as a whole to combat desertification and land degradation while endeavouring to preserve biodiversity.

The concept of sustainable development is at the heart of the activities proposed in the kit: as they implement them, the teachers or educators, with the help of resource persons, local partners and environment professionals, teach the pupils to critically evaluate local practices linked to land use and natural resource management. They identify the practices that may be harmful or non-viable for the ecosystem and in so doing gradually deepen their understanding of the impact of human activities on their environment. By engaging in practical activities, the pupils gain a better knowledge of sustainable development in dryland ecosystems.

Structure of the kit

The kit comprises three elements:

- the teacher's manual;
- the class notebook;
- the map of the world's drylands.

The teacher's manual is the central component of the kit. It is divided into three thematic chapters:

- Discovering the ecosystem and its biodiversity;
- Maintaining plant cover;
- Preserving water resources.

The first two chapters each contain seven activities and the third chapter contains six, ranked according to their level of difficulty in terms of content and implementation.

Each chapter begins with 'easy' activities, followed by 'intermediate' and then 'advanced' activities.

The teacher may choose to carry out the activities with the class one after the other in the order proposed in each chapter; one or more of the activities may also be conducted separately, in accordance with the themes being studied in class, the school timetable, and the ability level of the pupils.

The class notebook is used by the pupils and designed to accompany the teacher's manual. The notebook contains a double page spread to be filled in for each activity. The pupils are split into groups, and in turn, each group works together to fill in the pages set aside for the activity carried out. They use their own words, their understanding of the activity objectives, their visual and sensory memories of the exercise, their ability to draw upon and preserve knowledge learned and experienced.

The class notebook is printed in two colours so that it can be easily photocopied, making it simple for the teacher and pupils to exchange class notebooks with another school in the UNESCO's Associated Schools Project Network located in a different dryland region of the world.

Finally, **the map of the world's drylands** is designed to be displayed in the classroom. The teacher may regularly refer to it while the class carries out the various activities in order to make relevant comparisons between the local environment of the class and other dryland ecosystems.

Who is the kit intended for?

The kit is designed for secondary-school teachers of subjects as varied as geography, biology and art expression.

It may also be used by teachers of older primary-school children and, more generally, by any educator wishing to carry out an environmental education project, either alone or as part of a team, in a formal or non-formal educational setting.

As far as raising public awareness is concerned, the kit may also be used to promote the efforts of local decision-makers wishing to take environmental issues into account when drafting development policies.

Most of the activities in the kit, which require very little in the way of equipment, involve an element of environmental discovery (or rediscovery) based on observation, collection, drawing, imagination and meeting with local resource persons. The activities thus take into account the shortage of resources and the often difficult working conditions of teachers in dryland zones.

In summary, the form the educational project takes depends mainly on the teachers' motivation and ability to organize themselves and combine their efforts.

They may use the kit to develop an environmental education thematic project (along the lines of a themed class) or conduct activities in the kit as part of educational or pedagogical innovation projects. They may also use the kit as an education for sustainable development resource through the various dimensions proposed:
• cross-disciplinary learning objectives that extend beyond the scope of a single subject;
• methodology based on the development of critical thinking;
• participation of resource persons, local stakeholders and environment specialists in educational activities, supporting and enriching the teachers' contribution.

A creative approach to environmental education
All of the activities contained in the teacher's manual have been developed in accordance with a creative approach to environmental education. Initially, this approach encourages pupils to use their senses to discover the environment. Often living in rural areas, children in countries affected by desertification have concrete, pragmatic experience of their natural environment.

In order to carry out the activities, they venture outside and survey their natural surroundings, accompanied and guided by their teacher. They learn how to observe, to 'read' their environment better, to examine it in detail and to see things they may never have noticed before. They describe an object within reach on the ground or a species in its natural habitat and, always based on practical observations, learn new terminology and concepts. The pupils may rediscover an object by placing it next to or comparing it with others in collections and compositions that the class produces together.

On several occasions where necessary, the teacher invites the pupils to draw what they observe, since this often helps them to see and understand better. The aim is not to develop their drawing skills, but to help them become better observers of nature. They draw in order to remember a detail or capture a particular scene.

In other activities, the class learns to recognize and describe the smells and tastes of plants and foods and dishes derived from them. Others invite them to rediscover the relief of the land by placing themselves in the environment and to use certain exercises to compare the human scale with that of the landscape.

In short, the aesthetic and inspiring qualities of the environment are used to arouse pupils' curiosity and keep their attention. They can better understand what they have observed from close quarters, what they have experienced in an intimate way, what they have made their own and, to a certain degree, learned to love.

In the second phase, scientific information and environmental knowledge are passed on to the pupils in activities that rely on local and everyday knowledge placed in a scientific context.
These activities encourage exchanges with local holders of indigenous knowledge, such as shepherds, farmers, herders, foresters, trackers, medicinal plant experts and craft workers. Frequent reference is made to a three-way relationship between the teacher(s), these resource persons in the community, and the pupils: that relationship is built into the very methodology of the kit's activities.

At various stages in the activities, the teacher may choose to create a forum for discussion with local experts in the classroom so that the links between the ecosystem and local culture can be fully explored.
The transmission of knowledge, know-how and even of the oral tradition (through stories and anecdotes) is therefore facilitated.

The teachers then place this knowledge in a scientific context: how can indigenous knowledge be crossmatched with scientific data on the fragile ecosystems found in

dryland zones? How can it be combined with wider scientific knowledge of species conservation? How can it be linked to the sustainable use of natural resources? The pupils are thus led to develop their ability to think critically and the teacher helps them consider the impact of human activities on the environment.

In the activity *Form and Design: the Anatomy of Plants*, the object is to study the shape and growth of plants, particularly trees, and to learn how to identify them from a distance. The teacher makes use of the practical knowledge of local inhabitants and community elders. What criteria do local people use to identify a particular plant from a distance? They often walk long distances to gather wild fruit or to seek fodder, and are constantly striving to better cope with external circumstances; and they do this using empirical information they have gained and skills they have developed through daily contact with the environment.
Since it remains of practical use to local people, this empirical information is there to be transmitted by knowledgeable elders in the course of these exercises; it is then combined in the exercise with a more precise, scientific study of what a tree is, its architecture, anatomy and habit, the ecological functions it fulfils from roots to crown, the way a lone tree can constitute an ecosystem in itself, and the need to preserve it in its entirety in an environment where the ecological balance is fragile.

The idea is to encourage the pupils to consider the impact of external forces on the shape or habit of plants. Are these determined by the wind, by individual humans who gather their requirements without realizing what they are destroying, by the general impact of human activities such as overgrazing and feeding of herbivores?

An Inventory of Useful Plants – another activity in the kit – encourages the pupils to put the human being at the heart of the ecosystem: how essential is the part played by humans? In what way is the ecosystem vital to the well-being of every human? How does biodiversity respond point by point to the diversity of human needs? Seen as a source of crops and other benefits, the ecosystem is likened to a garden from which the community gathers fruit: a nourishing garden (edible plants), a healing garden (herbal essences and medicinal plants) and a protecting garden (the use of plants in building homes or making clothes). The pupils then consider how people preserve these natural resources in return.

In *The Plant as Mascot*, the class chooses a specific plant which plays a vital role in the everyday life of the local community. The pupils present and highlight the numerous 'services' that the plant provides for the entire population. They learn how to present, side by side, a specimen of the plant itself and all of the products and finished items derived from it, such as bars of soap made from olive oil taken from the olive tree *Olea europaea* or the pestles and axe and knife handles made from the hard, resistant wood of *Balanites aegyptiaca*, commonly known as the 'soap tree' or 'desert date'.
With the help of local experts, the pupils introduce into their presentation the notion of know-how with drawings depicting the manufacturing processes. The ingenuity of human beings is demonstrated by links between their tools, inventiveness and ability to manipulate, and the selected plant. The activity encourages pupils to identify specific forms of harvesting, production and distribution of the plant that are harmful for the ecosystem.

Finally, in *The Experimental Garden*, a team of teachers develops a practical educational project based on a garden. The activity includes an element of sustainable development, since it encourages the pupils to take long-term action, for the benefit of future pupils and generations as well as themselves.
The experimental garden itself is developed in conjunction with a land management programme described in the previous activity, *The Plant as Mascot*. The garden site is linked to locations chosen by local decision-makers for environmental protection projects. The schoolchildren will go back and forth between the testing ground of the experimental garden and full-scale areas cultivated by professionals such as farmers, foresters, smallholders and environment experts. During the activity, the pupils acquire practical and technical skills in gardening and agroforestry, which they back up and develop through contact with professionals.

How to use the teacher's manual
The layout of the teacher's manual is designed to be clear and appealing, reflecting the spirit of the project. The clearly marked colour coding of orange and sepia makes it easy to identify the division of the manual into three chapters and 20 activities. The orange on the cover is also found on the dividing strip between each chapter and again on the header of each numbered activity. This header includes the **title** of the activity as well as several graphic symbols that enable the teacher to identify and

use the pedagogical material. The following information is indicated:

The **level** of the activity: its level of difficulty in terms of content and implementation: Easy, Intermediate or Advanced;

The **place** where the activity should be conducted: outdoors, or in the classroom;

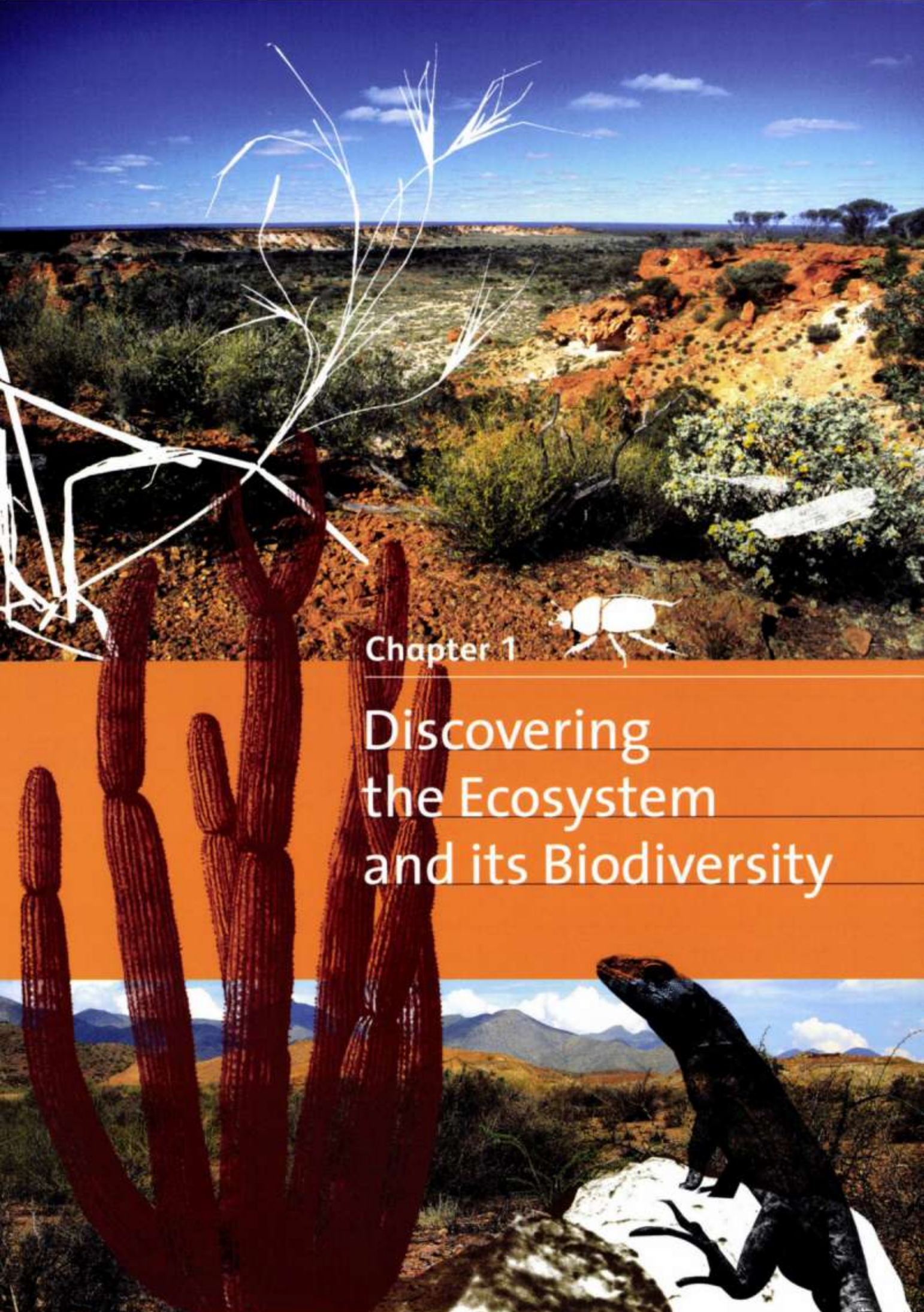
The **number of sessions** required in order to complete the activity: the length of a session, two to three hours on average, may be modified by the teacher according to the time available.

The **objectives** are also described at the start of the description of each activity, under the title header. The teacher can therefore easily identify the objectives of the activity, which are usually defined in terms of environmental discovery, knowledge to be transmitted and pupils' comprehension. Some advanced activities, in addition to transmitting knowledge, aim to develop certain aptitudes and skills.

The **methodology** to be followed for each activity is clearly indicated by the division of the activity into several sequential stages. Each stage is summarized by a verb indicating a specific action ('collect' or 'classify', for example) or a subheading in which the action is described ('observe the action of the wind and the signs of erosion', for example). This provides both a sense of dynamism and a clear order of progression.

Throughout the **description** of each activity, the subheadings are coloured orange, the colour used to organize the manual, and are therefore easily identifiable in the text. Examples illustrating each stage of the activity are shown in sepia, the colour which, along with orange, forms the colour code used throughout the teaching resource kit. The titles and subheadings also appear in the manual's table of contents, which, right at the beginning, provides an overview of the content of each activity.

Finally, scientific and technical terms relating to ecology and the environment are clearly identifiable: they are highlighted in pink and direct the reader to a **glossary** at the end of the manual. In this way, the teacher's knowledge base is strengthened and the requisite knowledge specified.



Chapter 1

Discovering the Ecosystem and its Biodiversity

01 Collecting Treasures

Level ★
easy

Place
classroom and outdoors

Duration
2 sessions

Objectives

1. Discovery of the environment

By collecting natural objects in their own familiar landscape, pupils become aware of the biological diversity of their environment. This exercise usually generates a sense of wonder.

2. Knowledge and comprehension

The process of classifying the objects and assembling them into collections gives pupils a first, visual notion of the terms 'biotope', 'biocenosis' and 'ecosystem'.

Methodology

1. Guide

► In drylands, the landscape can appear monotonous and austere.
Consequently, the teacher encourages pupils to explore the environment 'with a fine tooth-comb' and identify microhabitats where biodiversity exists to a greater or lesser degree.
► The teacher introduces the notion of **biodiversity**[1]: a general term used to designate the variability of the plants, animals and micro-organisms that exist on earth, their variability within a single species and the variability of the **ecosystems** to which they belong. By and large, biodiversity covers genetic diversity, species diversity and **habitat** diversity.

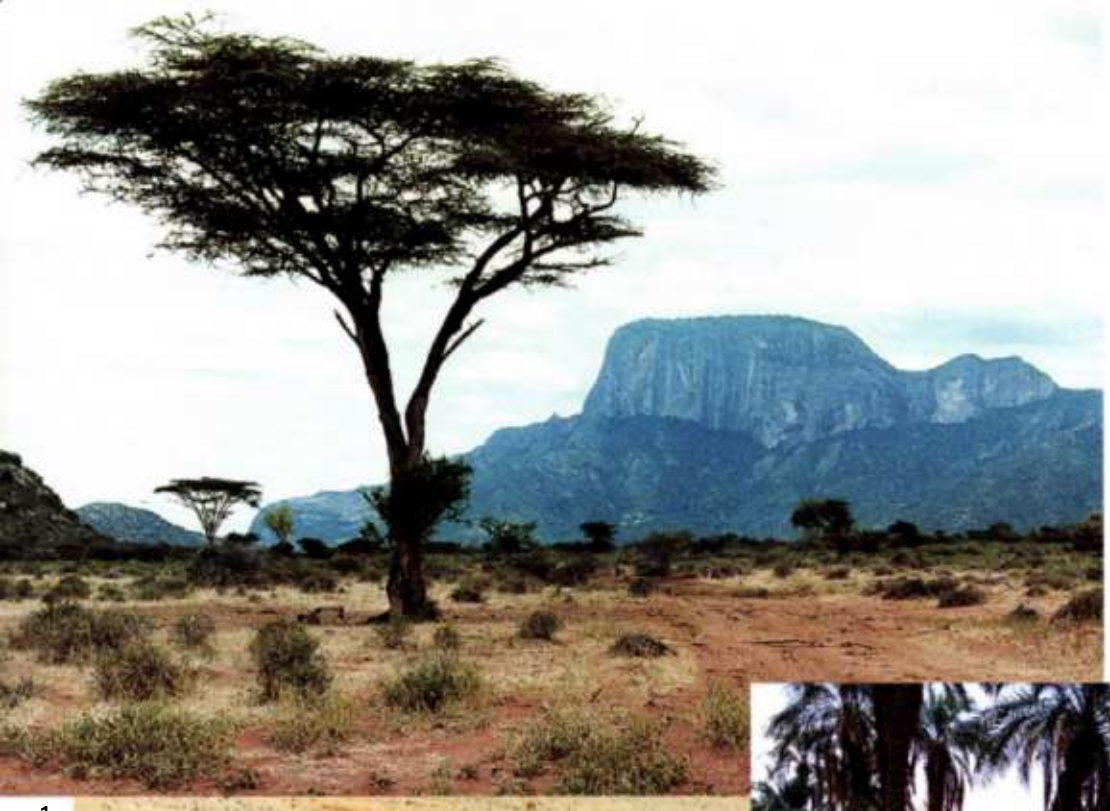
2. Identify

► In the desert landscape, usually characterized by uniformity, the teacher identifies at least two zones that are different from a geographical or **plant cover** perspective.
► Given the usually vast scale of arid regions, the teacher may allow the class to explore the landscape by vehicle.
► The class learns to observe variations in vegetation cover from one area to another, distinguishing a desert environment dominated by rocks from one with one or several vegetation strata, often covered with bush formations or plants that are characteristic of arid and semi-arid zones (such as the *saguaro* bush in Latin America).

Other potential examples of identifiable zones:

- A dry savannah or steppe zone;
- A more humid zone, such as a pond, a *wadi* (even when dry), the periphery of a watering hole or a riverside;
- An oasis zone containing cultivated plots or fields.

1. Terms highlighted in pink are defined in the glossary on p.194



1

2

3

1. *Acacia senegalensis* in a semi-arid zone, North Kenya

2. Palm trees at *Oued Guir*, *Tazzouguert* region, *Tamlelt* plain, Morocco

3. Palm grove, *Timimoun* oasis, Algeria

3. Collect

► Split into groups, the class explores the various identifiable zones in turn, collecting as many different natural objects as possible and placing them in different bags, one for each zone: fragments from rocky strata, unusual stones, soil and mud samples, small containers of sand, bush and shrub branches, leaves, stalks and tufts of grass, leaves and flowers of herbaceous plants (except the most fragile), fruit and grains of all kinds, cones, unearthed tubers and bulbs (irises, tulips, wild onions), root fragments, pieces of bark, fungi and lichens, fossils, dead insects (beetles, grasshoppers), empty cocoons, small mammal bones and teeth (fennec foxes, rodents), bird feathers, shells, eggs fallen from nests, the shed skin and scales of reptiles and so on.
What a surprise! These objects are like hidden treasures revealed in the palm of your hand.

4. Store

► The class can bring in old newspapers and magazines and preserve the plants they have collected by inserting them, spread out between the pages so that they keep their shape during the drying process.

5. Clean

► Where necessary, the pupils clean the objects carefully so as not to damage them.

6. Observe

► Back in the classroom, pupils study each individual object. It is interesting to learn about them by examining them from different angles, observing them in minute detail and comparing them with other objects of the same type (such as two fruits).
► The teacher asks the class to identify any similarities among the objects in terms of shape, texture and colour.

7. Identify

► Only then will the pupils proceed to identify the objects: what do they belong to?
Do they belong to the plant, animal or the mineral **kingdom**? Do they belong to the same species? Are they earth resources (such as soil, for instance)?

8. Classify

► The pupils classify their finds according to a set of distinctions:
Does it belong to the plant kingdom? Does it belong to the animal kingdom? Is it living matter? Is it dead matter?

9. Integrate concepts

► The teacher takes the children outside again in order to consider each object individually and evaluate it in its natural context. The teacher may also select the objects one by one from the pupils' collections.
► The idea is to start with the individual object (the smallest unit) and increase in scale through species and habitats to the ecosystem as a whole.
Example:
A particular object indicates a particular species. Its natural habitat is then explained:
How does the species occupy its habitat? What are its feeding habits?
► This is how the teacher introduces the concept of **biocenosis** – a community of living organisms (animals, plants and micro-organisms) that coexist in the same natural habitat.
► The teacher then introduces the concept of **biotope** – a defined natural area characterized by specific conditions that supports animal and plant species adapted to those conditions.

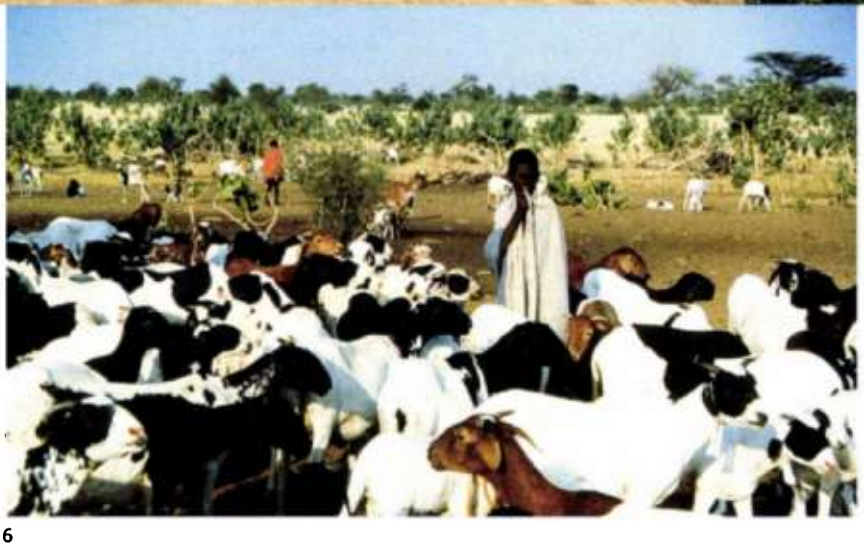
Examples:
In *nebkha* zones (sand dunes formed around plants by the wind, typical of some North African regions), bushes (salsola), insects, rodents (gerbils) and herbivorous mammals (gazelles and goats) cohabit and, consequently, share the same biotope.
By extension, the acacia and the giraffe, both of which live in one particular area of dry, wooded savannah, also share the same biotope.

10. Create collections

► Using this knowledge, the pupils will each create a collection based on their own finds and discoveries with the aim of presenting the objects they have collected in a visual form that illustrates the recently acquired notions of biotope and biocenosis.
A flat box or simple cardboard surface could be used to present each collection.
► The pupils recall the place where each object was found. What are the key characteristics of this landscape unit in the ecosystem?
► They then place each group of objects on a cardboard base representing a particular biotope. How might one illustrate the unity that exists within a community of living organisms in one place?
► They create a coloured background representing the soil of the biotope, or glue appropriate mineral samples onto the base. Sand could be sprinkled onto a layer of glue, for example, creating an effect that closely resembles the real thing in terms of texture and substance;

4

5



6

4. Mixed formation of woody and herbaceous plants in the dry season, Sahel
©UNESCO-MAB

5. Giraffe grazing on a bush, Sahel
©UNESCO-MAB

6. Young shepherd with a herd of goats, Sahel
©UNESCO-MAB

► They then place the objects representing the species present in the biotope on the base in a specific order, grouping them so as to represent the food chain or families of species, or kingdoms.
The pupils themselves propose how first to represent the ecosystem on the basis of their finds and the information initially provided to them, so as to illustrate the unity and diversity of a given habitat in the landscape.
► The teacher's role is to shape the collection according to the reality of the environment. Depending on the diversity of locally available habitats, the teacher might suggest focusing not only on the diversity of the collected objects, but also on their numbers and relative proportions.
► Consequently, the collection might draw comparisons between objects of the same kind (several types of leaf or several bird feathers, for example).
► This allows the teacher to bring in quantitative elements of a scientific nature and introduce more precise concepts, such as species richness and abundance, or, conversely, the rarity or decline of species that mark the difference between one biotope and another.
► With regard to species decline, the teacher introduces the notion of the impact of human activities on the conservation of the environment.
► The teacher also explains that an ecosystem can be regarded as a dynamic ensemble of interacting biotopes and biocenoses.
► And so pupils may create as many mini-collections as there are identifiable habitats, each collection corresponding to a specific biotope. These genuine 'collections of places' help pupils to comprehend the ecosystem by picturing it as an ensemble of separate units. This is the one of the ways ecologists study it.

02 Composing Shapes on the Ground

Level ★ easy

Place outdoors

Duration 2 sessions

Objectives

1. Discovery of the environment

By making shapes on the ground composed of objects taken from different areas of the countryside, pupils realize the diversity of the habitats that make up their environment.

2. Knowledge and comprehension

Looking at these compositions in detail, the teacher shows the pupils how to recognize and understand the many ways in which living organisms relate to each other, and their connections with their natural habitat.

Methodology

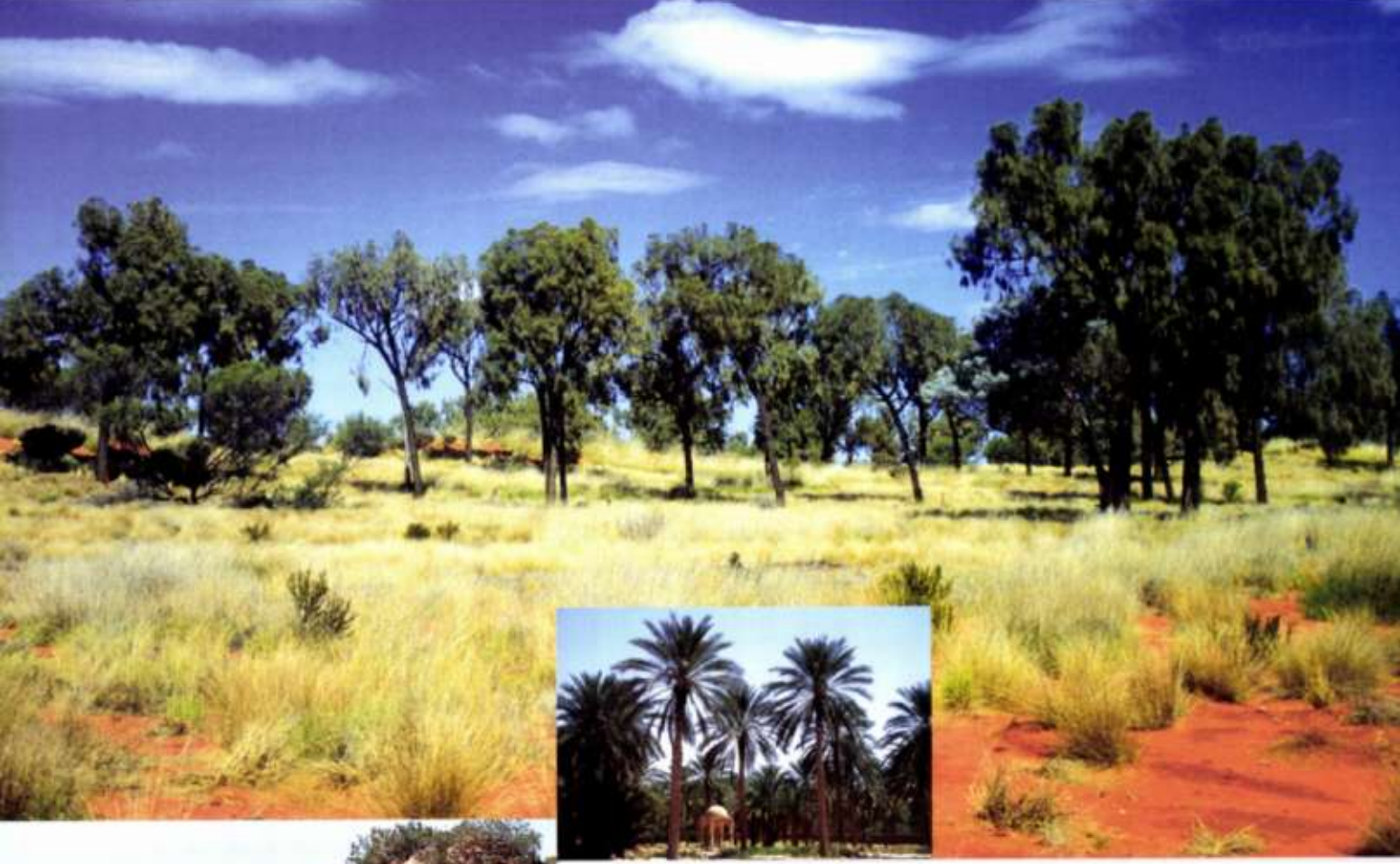
1. Choose a site for the compositions

► The teacher selects a place outdoors near the school, an area of bare land – preferably big, clear and flat – that can be raked and tidied to make a good background for these compositions on the ground. The colour of the chosen site matters too: ideally the minerals and plants brought from elsewhere will really stand out against this background.

2. Go to different biotopes and collect natural objects

► As with the last activity (*Collecting Treasures*), the pupils collect natural objects from a number of areas in the locality – different landscape units, with distinct types of flora and fauna. Depending on the dryland region concerned, these may include:
– bushy steppe with broken cover;
– dry forest with large trees;
– the area around a pond or watering hole;
– a bare and stony piece of rocky ground;
– dry savannah dominated by grasses;
– an area of bush with many thorny plants;
– an area of gardens or cultivated fields;
– a dry wadi;
– a palm grove in an oasis;
– an area where succulents grow (bush with cereus cacti, savannah with euphorbia trees);
– an isolated tree...
It is important to find at least two or three distinct zones.

► Pupils keep their finds in a separate bag for each zone (remember to include plenty of stones and pebbles of all sizes and colours from the rockiest biotope).



8

9

7

7. A working wadi, Tunisia
©Michel Le Berre

8. Palm trees in *Tolga*, Algeria
©Olivier Brestin

9. Desert oak trees,
Kata Tjuta region,
Northern Territories, Australia
©Olivier Brestin

10. *Festuca orthophylla*,
Socaire region, *Atacama* desert,
Chile
©UNESCO/Olivier Brestin

11. Desiccated soil surface,
San Pedro de Atacama, Chile
©UNESCO/Olivier Brestin

12. Farmer, *Timimoun* oasis,
Algeria
©Olivier Brestin

11

10

12

3. Prepare to make a shape on the ground for each biotope

► Back at the chosen site, the pupils prepare to create shapes on the ground using the objects they have collected.

Guided by the teacher, they choose simple, clearly identifiable shapes. We suggest using some pupils' shadows to make a human silhouette on the ground with the collected objects.

Hints and tips:

Choose a time of day when the shadows will be life-size (when the sun is approximately 45° above the horizon). The weather should be sunny but not too hot, and not windy so that the objects are not blown away.

► There should be one silhouette for each unit of the ecosystem represented.

Example:

If three landscape areas or biotopes are chosen from the list above, three silhouettes should be created, using items all collected from one biotope for each silhouette.

4. Create shapes on the ground from the collections using pupils' shadows

► To create each silhouette, one pupil stands still with outspread arms while the others make the shadow into a design on the ground using objects collected from one biotope.

► They mark the outline of the silhouette with stones, and then fill in the various parts of the body with other items from that collection.

Examples:

For a riverside or watering hole, the silhouette could be covered with leaves or tree branches – tamarisk (*Tamarix aphylla*) or sycamore fig (*Ficus sycomorus*) – a little white sand, some leaves or stems from annual plants or grasses – cattail (*Typha sp.*), reeds – or perhaps some knotweed gathered from the water, or some bird feathers. The silhouette for a dry grassy savannah area could be covered with various grasses, simple leaves or seed-ears (such as *Heteropogon concortus* in Africa), the bipinnate leaves of many acacias (*Acacia senegalensis*), the curiously shaped pods or fruits of others (*Acacia giraffae*) or, in season, beautiful yellow flowers (*Acacia seyal*). If possible, decorate the silhouette with bird feathers (big feathers from a vulture, or red and blue feathers from doves like *Streptopelia senegalensis*); it could have bones or horns from hoofed herbivores such as gnus, antelopes or gazelles, or small mammal bones. Savannah has one of the richest faunas of all.

► Working in groups, the pupils create a composition in this way for each of the biotopes to be represented.

13

14

15

5. Study the compositions in detail

Group study of the compositions is important.

► The pupils give their individual interpretations of each composition's visual impact:
Composing a shape – in this case a silhouette – by putting various objects side by side on the ground leads the pupils, as they study the whole composition and explore its details, to notice the various objects' physical characteristics and the differences among them (a natural exercise of perception, moving from the whole to the parts).

Example:

Again in the case of dry grassy savannah, pupils can notice the luxuriance and density of the grasses (green or yellowing, depending on the season), their bright silvery or golden inflorescences, the tender greens of the acacia shoots or their vivid pods so ideally suited to graphic design, and the intriguing or surprising look of certain flowers or fruits – of baobabs, for instance, or the sausage tree (*Kigelia africana*).

► As the pupils continue to look at the composition in detail, they can distinguish and count the various species present in the biotope. If there is no real diversity, it is important to include, if possible, one or more objects of animal origin to represent a biotope (bones, snail shells, cast-off reptile skins, or dead insects – darkling beetles, perhaps, or scarabs). The Sahara, for example, is home to around 130 species of mammals, 60 nesting birds and 100 reptiles.

► Three different silhouettes should be enough to convey the idea of species and habitat diversity, and of variability among habitats.

It is worth noting that there will be aspects common to these compositions from areas of 'semi-desert' (in its broadest sense) in many different parts of the world.

13. Shrub savannah, during the dry season, W region, Niger
©Michel Le Berre

14. Male impala (*Aepyceros metampus*), Kenya
©Michel Le Berre

15. Shea tree (*Vitellaria paradoxa*), W region, Niger
©Michel Le Berre

16. Shrub savannah, during the rainy season, W region, Niger
©Michel Le Berre

17 et **19.** *Acacia seyal* in bloom, W region, Niger
©Michel Le Berre

18. *Prosopis tamarugo* seeds, *Atacama* desert, Chile
©UNESCO/Olivier Brestin

16

17

19

18

Examples:
The tender green foliage of plants such as the astragalus in Tunisia resembles the Mexican *ocotillo*, while the twisted branches of the creosote bush in Mexico are similar to those of *Zilla spinosa*, a typical plant of Sarahan or Arabian landscapes. The brightly coloured flowers of **ephemerophytes** or bulb plants (irises and lilies) in the *wadis* of southern Tunisia are reminiscent of the equally vivid flowers of cacti in Latin America.

6. Put concepts together

► The teacher examines the composition of each silhouette and interprets the biotope it represents, asking the pupils questions to remind them of the site of collection.
► The teacher explains the relationships between the species present in the composition and the place where the specimens were gathered:
• Living organisms are affected by their habitat: their lives depend on **resources** (water, soil quality, nutrients, light), and are determined by **conditions** (temperature, wind).
• The teacher explains: living organisms are also affected by the other species around them.
– Species relate to each other directly through the **food chain.**
Examples:
The jerboa (small rodent) eats fruit, dry seeds and leaves; the gerbils of the Sahel gnaw at tree bark to get water; carnivores like jackals, fennecs and sand foxes eat rodents; animal carcasses are eaten by detritivores (necrophages, ants, and millipedes). Matter that is not eaten by **detritivores** is broken down to dust by micro-organisms called **decomposers.**
– Relationships between species can also be less direct and less readily identifiable. Species with similar needs usually compete with each other: depending on how much water is available, two different plant species will compete for it more or less intensely.
– Many species depend on others to complete their biological cycle: flowering plants are pollinated by insects and birds.

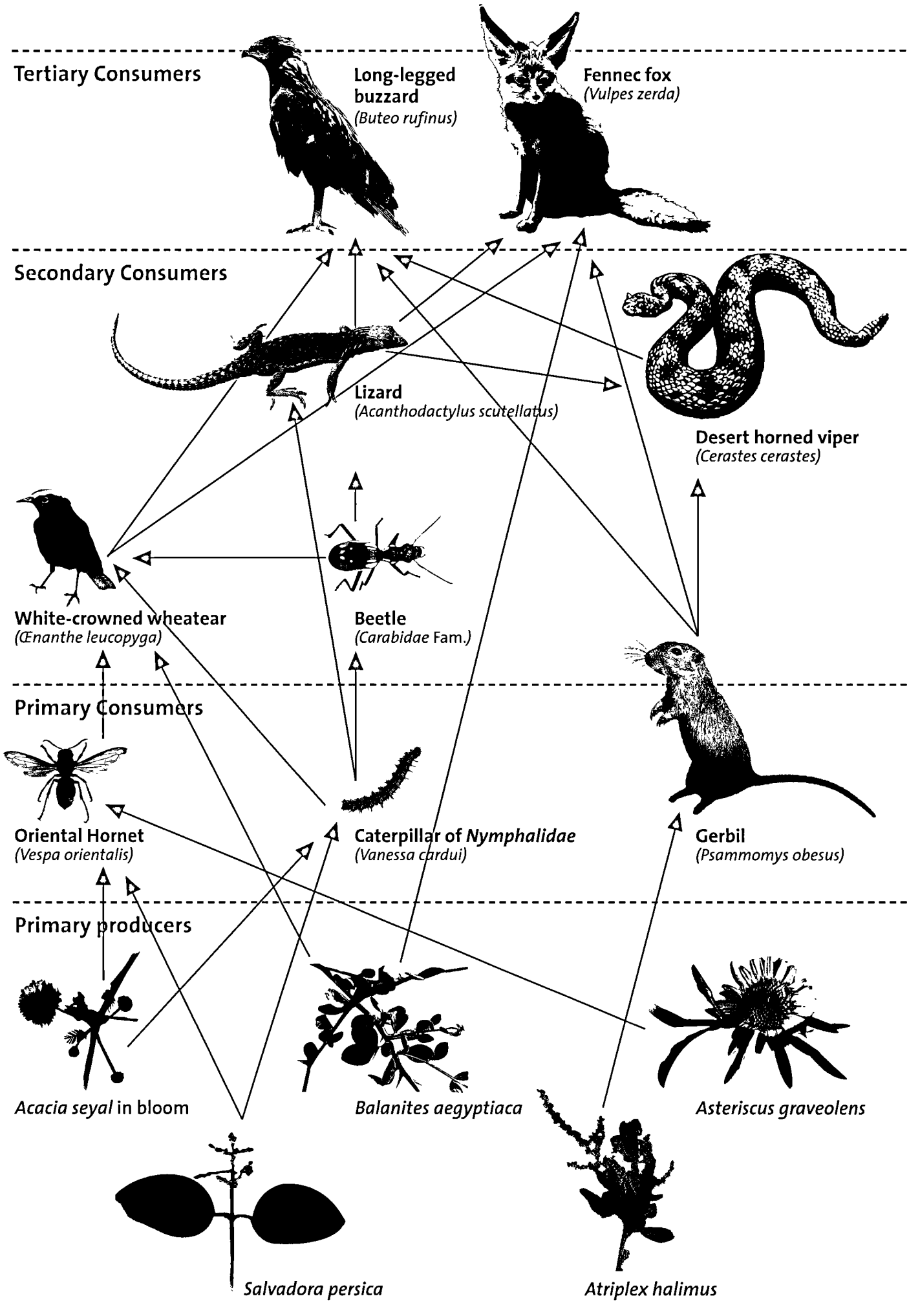
7. Bring these concepts to life by making up a story

► Once the teacher has explained how species relate to each other and to their habitat, the pupils focus on one silhouette and make up a story which brings together and connects the composition's various items.
► The idea is to emphasize the relationships described by the teacher (species/resource relationships, the food chain, competition, interaction) by getting the pupils to make up a story in their own words, with a narrative flow moving freely and rapidly from object to object without a break.
► In composing their story, the pupils can include some imaginary elements (*Once upon a time...*), providing that their interpretation of the biotope and of the way it functions is consistent with what they have just learned.
► The teacher then points out any inconsistencies.

8. Link the compositions together in the story

One advantage is to have the pupils, whose shadows are used for the silhouettes, to hold their arms outstretched so that the resulting compositions can then touch one another: this suggests the idea of linkages and interactions between the different biotopes, which is part of the functioning of the ecosystem as a whole. This idea of a number of overlapping cycles can be built into the story.
The idea of linkage is also reinforced by carrying out the activity collectively.
Using the pupils' silhouettes to make these compositions is also a symbolic way to situate human beings and human concerns at the heart of the environment.

An example of trophic dynamics in the Saharan region



03 Land, Rock and Erosion

Level ★★ intermediate

Place outdoors

Duration 2 sessions

Objectives

1. Discovery of the environment

Through learning about relief formations and the constitution of the geological landscape with their teacher, the pupils establish a relationship between rock and soil quality, and between rocks and sediments.

2. Knowledge and comprehension

After several brief interventions in the mineral landscape (tracing shapes and making sculptures), the pupils visualize the phenomenon of erosion through a series of drawings (in particular wind action in drylands), and understand the importance of soil nutrients in the ecosystem.

Methodology

1. Identify the mineral

In drylands, it is often the rock rather than the vegetation that characterizes the landscape.

► The pupils and teacher select one or more points in the landscape where mineral elements predominate.

2. Observe the geological dimension of the landscape

The class visits the site with the teacher and learns about relief formations and the constitution of the geological landscape;

► The teacher describes the type of rock that comprises the landscape:

This could be sedimentary rock, formed by the deposition and cementation of the weathered remains of other rocks (shale and sandstone), the results of biogenic activity (limestone), or by precipitation from solution (halite or gypsum).

► The pupils probe the soil in several places within the landscape:

They discover that it consists of **sediments** produced by the degradation of the rock that composes the relief – fragments of disintegrated or eroded rock, such as stones, pebbles, sand, silt and clay. The soil may have formed a thick deposit or a thinner one, such as a fine veneer on block fields or large rocks. The pupils identify this phenomenon by moving around the landscape.

► The pupils are encouraged to make the connection between stones scattered here and there and the rock that comprises the relief:

The teacher explains geological formation as it occurs (for sedimentary rocks) through sediment accumulation; in other words, by strata or superimposed layers that are visible for example in sandstone, in the horizontal stratification of the plateaux and tables that are characteristic of the relief of drylands, and in stones scattered over the ground. For a better perspective, the pupils can split or break fragments or slabs of rock, the easiest being cleavable rocks such as shale, slate, some sandstones and limestones, and calcschists.

20

20. Dunes of the *Namib* Desert, *Swakopmund* region, Namibia
©Yann Arthus-Bertrand
La Terre vue du Ciel, UNESCO

21. Mountains at *Brandberg West* (2,573m), *Damaraland* region, Namibia
©Yann Arthus-Bertrand
La Terre vue du Ciel, UNESCO

21

3. Make the connection between soil and relief and place oneself in the landscape

► Next, the pupils make the connection between the soil under their feet and the relief in the distance through a number of brief interventions in the landscape:
In doing so, they will handle mineral matter by creating sculptures from collections of stones and sediments (tumuli, cairns, circles), tracing figures with their feet and creating chromatic compositions using minerals.
► The teacher encourages them to establish a proportional scale (human scale, natural scale) between their interventions and the landscape:
• A propped-up stone or an artificial **tumulus** a few score centimetres high could represent a major landscape relief. These creations, arranged in the foreground for the benefit of the viewer with the relief as backdrop, appear as large as the background relief and reflect its appearance and texture. The similarity is striking!
• A straight line traced with the foot on flat ground and symmetrically aligned with the relief may, owing to the effects of perspective, create a link between the person on the ground and the relief in the distance, between the human scale and the landscape scale, and between the ground and the vertical form of the relief.
These sculptures or artificial drawings introduced in the landscape also represent evidence of human endeavour in vast natural expanses: a way for pupils to capture two kinds of action and creation – the human and the natural– and become part of the landscape.

4. Identify wind action and erosion marks

► With their ground drawings, the pupils notice the visibility of the marks made by their feet. On breaking or lifting the top layer of the ground's surface, they see how the marks appear darker or lighter than the original ground.
The teacher points out the **desert varnish** (or eolian polish) coating the ground and rocks.
► This allows the teacher to change themes and introduce the role of the wind in shaping the contours of the landscape.
The teacher first reminds the class that **erosion** is the process by which the earth's surface is worn away and transformed by agents such as water, wind, ice and heat.
The teacher then explains that **eolian erosion** is the process by which winds erode the earth's crust by wearing away rocks, thereby changing the contours of the relief.
The teacher may use examples to illustrate **corrasion** – the abrasive effect of wind containing grains of sand or quartz on landscape reliefs and ground surfaces. The teacher also explains

23

22

24

22. Rock engravings in *Tinhert*, *Tassili N'Ajjer*, Algeria
©Olivier Brestin

23. Tuareg, *Tamrit*, *Tassili N'Ajjer*, Algeria
©Olivier Brestin

24. Dromedary and Tuareg footprints, *Admer* erg, *Tassili N'Ajjer*, Algeria
©Olivier Brestin

25

25. Laminated sandstone, *Saoura* valley, *Béni-Abbès*, Algeria
©Michel Le Berre

26. *Saoura* gorges at *Marhouma*, *Béni-Abbès*, Algeria
©Michel Le Berre

26

27

27. Cairn or *redjem*, north of *Illizi*, *Tassili N'Ajjer*, Algeria
©Michel Le Berre

28. Variation of sandstone colours in *Marhouma, Béni-Abbès*, Algeria
©Michel Le Berre

29. Desiccated soil surface, Atacama desert, Chile
©UNESCO, Olivier Brestin

30. *Ougarta* mounts, *Béni-Abbès*, Algeria
©Michel Le Berre

31. *Bou Hafinia* region, Algeria
©Olivier Brestin

29

28

30

31

32

33

34

32. Eroded rock, *Tamrit* region, *Tassili N'Ajjer*, Algeria
©Olivier Brestin

33. Abandoned Tuareg camp, *Admer* erg, *Tassili N'Ajjer*, Algeria
©Olivier Brestin

34. *Ischigualasto* geological formation, Moon Valley, *San Juan*, Argentina
©UNESCO/Liliana Madrid de Zito Fontan

deflation, the process by which winds lift and transport small particles from the ground, depositing them to accumulate elsewhere (dune displacement).
The teacher concludes by pointing out that, contrary to what one might expect in drylands, water erosion (fluvial erosion, seepage into the water table) often has more impact on the landscape than eolian erosion. Nonetheless, eolian erosion is a form of surface erosion that is harmful to soil productivity. Finally, the teacher mentions the important role of thermal erosion in the fragmentation of rock blocks in drylands.

5. Draw

► The pupils go on to identify one or more instances of eolian erosion, and comprehend, through drawing, the 'plastic' effect of winds on the landscape.
Equipped with sketch pads, they may (depending on the location and context):
• Capture the crumbling rock that forms worn rocks and jagged reliefs created by the uneven forms;
• Portray the formation of dune masses by 'sketching' the dunes according to the direction in which the crest is moving, one side in sunshine and the other in shadow, highlighting the curves and the contrasts in the light;
• Draw 'close-ups' of jagged ridges emerging from soft ground or unusual (sometimes hollowed-out) rock contours;
• Depict furrows made in the sand or in fossilized sandstone by the wind, by drawing parallel serpentine lines and using contrasting tones (light/dark).
The bareness of the landscape is reflected throughout.

6. Interpret the drawings, and understand the effect of eolian erosion on the environment

► The teacher facilitates the interpretation of the drawings and explains how wind action is the cause of degradation in soil that is impoverished by drought or over-use by humankind.

The (fertile) topsoil is blown away by deflation; the rock is scoured and exposed; living organisms become scarce.

► The teacher establishes a causal relationship between absence of vegetation and intensity of eolian erosion: wherever the earth is unprotected by vegetation, the wind easily carries sediments away in the form of sand and dust clouds. And the more intense the deflation, the more it lays bare vast expanses of terrain, to the detriment of the flora as plants cannot grow without soil (except lichens).

7. Identify an area of land that is protected from erosion

► The pupils identify an area that is less bare or exposed to the wind than the areas they have just surveyed.

• What is it that protects the area from the wind? Its orientation? Relief topography? Human developments, such as green barriers of tree and bush plantations? Windbreaks or hedges made of branches or palms?

• Is it a more humid area? A fertile area? A farming area, or an area of wild vegetation?

• What are the constituents of non-sterile soil?

► The teacher points out that, as well as particles of soft rock (sand, clay), a fertile soil is made up of **humus, nutrients**, water, air, identifiable living elements or organisms such as roots, worms, detritivorous organisms and other, invisible organisms such as fungus filaments, bacteria and other micro-organisms.

8. Take earth samples from several locations and study their physical qualities

► The pupils proceed to take soil samples from the various sites visited in the course of the exercise. These samples are conserved in transparent receptacles which serve to display their composition, texture and colour.

Examples:

Where soil is exhausted or has been swept away, the pupils can take a little sand, white if from gypsum terrain, yellow or orange if the quartz in the sand is heavy in metal oxides.

From other points in the landscape, they can take heavier samples of silty or clayey earth (bringing out the different qualities of various clays).

They may also take a bit of mud from a riverbank or riverbed or from a watering hole.

► The pupils conclude the sampling exercise by wetting their samples and rubbing them on to paper or material in order to reveal the different colours of the soils.

35. Cypress, *Tamrit* region, *Tassili N'Ajjer*, Algeria
©Olivier Brestin

35

36. Sand dunes, *Hassi Khalifa* region, Algeria
©Olivier Brestin

36

04 Nature's Palette

Level ★★
intermediate

Place
classroom and outdoors

Duration
3 sessions

Objectives

1. Discovery of the environment

By rubbing or pressing minerals or parts of plants directly onto a taut piece of cloth (white cotton or linen), the pupils can display the range of colours present in the landscape, and find a new way of 'capturing' the diversity of living organisms and habitats in the ecosystem.

2. Knowledge and comprehension

By studying the natural colouring materials which local people use for dyeing and painting their textiles, leather, wood, pottery and even their own bodies through their use of colour in craft work, the pupils come to appreciate the close physical way in which humans relate to the ecosystem.

Methodology

1. Collect-Pick

► Depending on the region where they live, the pupils gather a variety of colouring agents from the natural environment: mainly plants (berries, leaves, flowers, all kinds of fruit, bark, mushrooms) or minerals (rocks, clays, or mud-brick).

By following the advice of local experts, they can locate ochre deposits, different types of colouring earth and **tinctorial** muds (*Bogolan* in Africa), and collect samples.

2. Guide

►The teacher helps the pupils to select the right articles, which are crushed, rubbed or pounded to extract the pigmented juice, sap or powder.

The teacher is advised to carry out tests beforehand, and to go for brightly coloured flowers and juicy leaves which actually contain colouring sap – not all fleshy foliage does.

Examples:

Possible choices in Africa – depending on the region, and with seasonal variations – include the inflorescences of trees such as the various species of acacia, and inflorescences such as broom (yellow), weld, wild sorrel (red), *mongo*, *pitaya* (dragon fruit), safflower (or false saffron), calendula or marigold, asters (sunflower, fleabane and others), or euphorbia flowers.

In oases and agricultural areas, strong pigments can be found in carrot tops and tomato leaves.

Try fresh indigo or henna leaves; grate a small amount of walnut bark; or use pomegranate rind.

In South America there are the fruit and flowers of various cacti, or *Calendrinia* and *Cristaria* for pinks and mauves.

Also consider natural dyes of animal origin such as the *Coccoidea* for a crimson dye (**cochineal**).

► The teacher should also help the pupils identify rare or protected species that should not be collected or removed, as well as species that are dangerous or toxic to humans: henbane, for example, or giant milkweed, which must be handled very carefully.

3. Share

► The pupils pool the colouring agents they have collected so as to widen the range of colours.

4. Rub-Crush-Spread

► The pupils then transfer the colouring matter onto a piece of white cotton stretched over a supporting surface (held in place, for instance, by brackets on either side of a pupil's desk). Minerals may be dampened so as to transfer their colour more effectively.
The idea is to reveal the diversity of colours available, while keeping to a single overall vision for the composition. Several cloths could be produced by small groups, or the whole class could make one big communal cloth, individual pupils fitting in with each other as they find a spot to work on until, in the end, the whole cloth is covered.
This exercise is designed to be a collective activity carried out spontaneously in a single session with a view to achieving a kind of swift and magical transfer of the colours of the local surroundings. The better the choice of materials, the more stunning the visual impact will be.

► In the second part of the activity, the class concentrates on the natural pigments that people use for dyeing and painting: dyeing of textiles, leather, wood, coloured or painted pottery, decorating of adobe walls, body painting, and tattoos.

5. Help find local knowledge

► The teacher encourages the pupils to identify and consult people with local knowledge and expertise in dyeing, dye plants and animal, mineral or vegetable colouring materials generally.

37

37. From left to right and from above to below: Nolana flowers (*Nolana paradoxa*), mimosa, bougainvillea, mimosa (detail), prickly pear fruit, tomato plant flowers
©UNESCO/Olivier Brestin

38

38. Indian sorrel flowers or bladder dock (*Rumex vesicarius*)
©Michel Le Berre

39

40

39. Tuaregs, *Admer* erg, *Djanet*, *Tassili N'Ajjer*, Algeria
©Olivier Brestin

40. Tuareg musician wearing an indigo-dyed turban, *Hoggar Tassili*, Algeria
©Olivier Brestin

Sketch of an indigofera branch

6. Link colour to the ecosystem

► Talking with these experts, the pupils learn to link particular colours with the plant species or minerals from where they originate.

This relationship is not something learned in an abstract way. On the contrary:

– The pupils concentrate on the limited palette of colours locally available in nature;

– They start with an object – a painted pot, a dyed garment – and with the help of the experts go through the different stages of its production, right back to the plant, the roots or the earth from which the colour came;

– The experienced dyer may demonstrate certain actions or techniques, or take the pupils to the places where the raw materials are collected, show them where the dyeing takes place and explain how the utensils are used. The pupils draw quick sketches of these various stages;

– They can then clearly see the connection between a particular colour and the corresponding raw material in the ecosystem.

Examples:

Between the yellow of a garment and (depending on the region) weld, kola nut, safflower or any of a number of wild mushrooms;

Between the red of a ceramic vase and red ochre; and between red body paint and either henna leaves or red ochre;

Between the blue of a turban and the indigo dye that comes from indigofera leaves.

7. Realize the cultural importance of natural dyes

► Once they have made this connection, the pupils become aware of the cultural importance of environmental resources:

• From the natural colouring materials available in the local ecosystem a palette of colours has emerged over time; as generation succeeds generation, this has led to the development of techniques for transferring these colours.

• When raw materials have been in short supply, or as the environment has changed, these techniques have had to be adapted: their evolution is a part of human history.

► The teacher offers a further idea:

As well as the traditional techniques and their evolution, there are symbolic connotations to every colour for the local people.

8. Discover how to make dyes

► Under the guidance of guardians of local knowledge the pupils discover the secrets of each colour's different shades, the various stages of picking and gathering, the lengthy soakings, the grinding and decanting, the way the different substances change and interact (with added ingredients, for instance, such as a **mordant** to help the colour penetrate the fibres). They also learn about the symbolic meanings that colours can convey.

Examples:

The pupils learn about indigo dyeing.

Indigofera leaves are steeped to ferment in what is known as an 'indigo vat', to extract the indican.

Natural sources of sulphide are used in this extraction process.

When the dyeing is finished, the cloth can be given a sheen by pounding on a block of wood.

Such dyeing is often done by women, and can be associated with the cult of guardian spirits which watch over women's life and work.

Pupils could also find out about gathering henna leaves in summer, or how to get red ochre by puddling the right kind of clay with water and following the process through to the settling tanks where the lumps are cut into pieces and set out to dry.

This can also provide the subject for some interesting drawings.

Next the pupils could study the many different ways in which ochre is prepared, depending on whether it is to be used for body painting, the decoration of adobe walls or dyeing cloth.

Lastly, they can concentrate on the symbolic aspect of the colour red, and its omnipresence in rituals from initiation rites to funerals; for red is the most ambivalent of colours, indicating both the power of fertility (or virility) and the excesses and dangers of that power. This is why in many dryland societies red (ochre) paints are used to decorate boys' and girls' bodies at puberty, and henna rouge is a core feature of engagement or wedding celebrations.

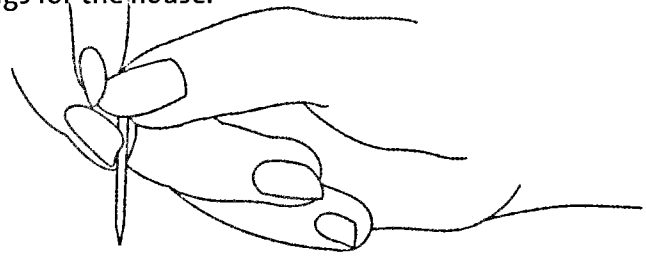
9. Introduce the subject of biodiversity conservation for debate

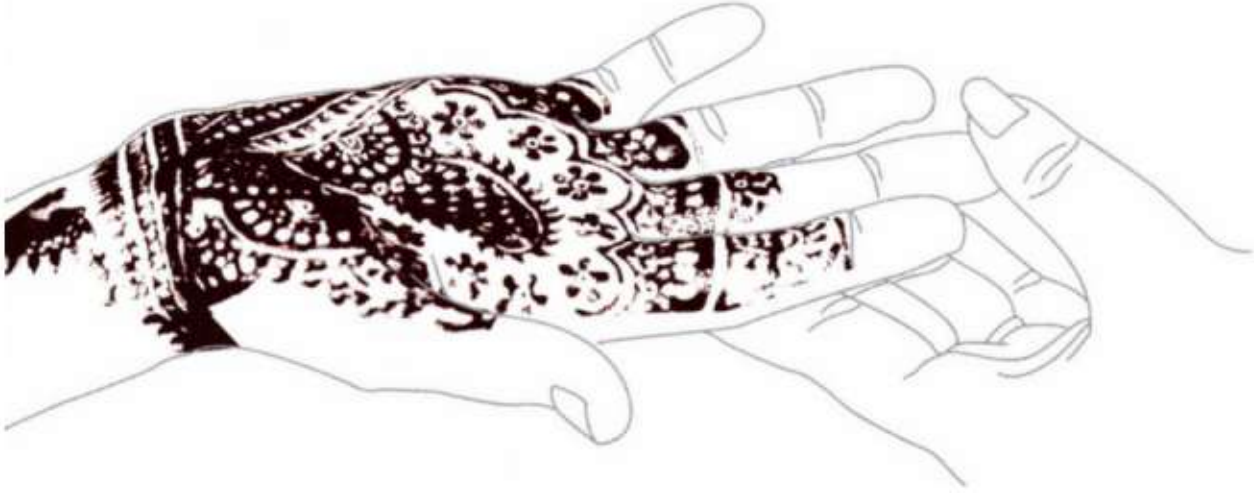
► The whole class discusses the conservation of natural colouring resources in the local ecosystem.
• Have some plants disappeared?
• Has diminishing biodiversity played a part in the disappearance of traditions and symbols in cultural practices?
• Is the use of natural pigments for beautifying bodies and colouring clothes one way of keeping a physical and symbolic connection with the land and local species?
• Even if printed textiles and synthetic colours have become commonplace, is it not possible for the population to continue using and valuing their own natural colourings as a link between their human society and their environment?

10. Dye it yourself

► At last the pupils are ready to tackle dyeing in practice: they learn to use the special techniques for soaking, fermenting, mixing and powdering whichever dye they are to use.
► For weld, for example, they break up approximately 1 kg of dried plant and leave it to soak in a copper pot.
► Meanwhile, they take thoroughly washed textile fibres, T-shirts or any other fabrics, and boil them in water containing a mordant such as alum.
► Next, they put them in the pot containing the weld, bring it to the boil letting it simmer for approximately 1 hour.
► Then they leave the cloth to cool in the dye bath, and rinse it with clean water.

The pupils can also use the dye they have made to print patterns on white cotton cloth with dye-soaked plants or fungi. This is a clever way of using up the left-over dye to make a wall hanging or stencilled drawings for the house.





05 On the Tracks of Wild Animals

Level ★★
intermediate

Place
classroom and outdoors

Duration
3 sessions

Objectives

1. Discovery of the environment

To get closer to animal species in their natural setting by listening to sounds, following tracks and recognizing other perceptible clues.

2. Knowledge and comprehension

From a review of the characteristics of animal species in the drylands, learn how to use story-telling to highlight the relationship between an animal and its biotope and get a better insight into how the same environment can mean different things to different species using it.

Methodology

1. Carry out an initial survey

► The pupils go out into the surrounding country on a quest for wild animals.
They try out a discreet approach and discover techniques of quiet observation which call for prolonged self-control, lurking in silence and avoiding any sudden movements in the hope of spotting animals in their natural habitat and observing their real-life behaviour from close quarters.
The wild species that are most readily observed in dryland areas are insects, lizards and some birds (especially in oasis regions); so the pupils naturally make the connection between observation and listening. Equipped, if possible, with a tape recorder and microphone, they record the sounds of the habitat and its animals.
If recordings are not possible, the pupils can simply listen.
► The pupils go out searching for wild animals at different times of the day: early morning or late evening (in the case of some nocturnal animals, listening to sounds is the best way of detecting their presence). They also venture out in different weather conditions, such as just after rainfall (in the rainy season).
► After several sessions, once they are more familiar with recording techniques, the pupils can use any more sophisticated equipment their school may have for analyzing the pitch of different sounds or making micro-recordings (on the ground or in trees) to detect animals' furtive rustlings and movements.
What a thrill, after such an effort of concentration, to spot a rodent hurrying by and to record its sound; or a snake – or even a fennec fox in Africa, a dingo in Australia or a coyote in Mexico.
In semi-desert zones such as wooded savannah, it is easier to observe large mammals such as ungulates.

► As they analyse their listening sessions afterwards, the pupils identify species from their sounds; They try to connect them with particular situations: are they the noises of a startled animal? Are the calls meant for intimidation (to frighten an enemy), raising the alarm, or for seduction (to attract

41

42

43

44

41 and **44.** Snake tracks in the sand, border of *Aïr* and *Ténéré*, Niger
©Michel Le Berre

42. Caravan of camels in *Djerat* wadi, *Tassili N'Ajjer*, Algeria
©Michel Le Berre

43. Bird prints in the sand, *Hassi Khalifa*, Algeria
©Olivier Brestin

the opposite sex)?
Is there anything about each call that gives a clue to the species' way of life? How can we tell? What does the animal eat? Is it a predator?

2. Identify animal tracks

This activity will benefit immensely from the help of an experienced tracker who is used to identifying animal tracks left in soil and sand; these tracks are like signatures on the ground, tell-tale signs of hidden activity the night before or very early in the morning.

► The pupils set off to investigate, guided by the tracker.

► They learn to recognize signs of burrowing and temporary shelters for escaping the heat, made by animals such as the golden mole (*Eremitalpa granti*) or the horned viper (*Cerastes cerastes*).

► They find the traces of special ways of getting around, like the sideways locomotion of rattlesnakes.

► They learn to identify the tracks of mammals such as ungulates in Saharan and sub-Saharan Africa by the width of their footprints.

Example:

The broad print of the camel is easy to recognize; the two deeper toe-marks at the front of the main print show which way the animal was walking.

► Pupils can distinguish the peculiar tracks of rodents which give the impression of a three-legged gait, such as the little Egyptian jerboa (*Jaculus jaculus*), whose small front paws touch the ground

together.
► They also learn to recognize the lace-work of insect tracks, the wavy traces of centipedes and insect larvae, and the footprints of flocking birds.

► In semi-arid zones, the class may set itself the task of finding tracks of endemic wild species.
Examples :
The tracks of marsupials in the Australian bush and steppes, or those left by the thousands of ungulates which criss-cross the dry grassy plains of Africa.
Generally speaking, savannah and semi-desert steppe are rich in birds of prey (eagles, owls) and running birds (African ostrich, American Rhea, Australian emu).
The pupils might find any of these tracks in the mud or sand near watering holes.

► Once the tracker has taught them to recognize such tracks, the pupils draw quick sketches of them in their sketchbooks.
► They bring out the details of each footprint (round, star-shaped, elongated, spaced out, or trailing). Do the drawings clearly show pads on the animal's feet?

45. Gnu or blue wildebeest (*Connochaetes taurinus*), Kenya

46. Shrub steppe, Bookmark Biosphere Reserve, Australia

47. Dromedary, *Kata Tjuta* region, Northern Territories, Australia

48. Female ostrich (*Struthio camelus massaicus*), Kenya

45

46

48

47

49. Rhinoceros, Kenya

3. Find other indications of species' lifestyles

► With the tracker's help, the pupils look for different clues to the presence and lifestyle of one or more species.

The tracker and teacher together remind the pupils of the precautions they should take and the rules they must observe during this exercise:

Avoid disturbing the animals, destroying shelters or burrows, breaching territories, destroying key plant species that constitute animals' food or habitats; do not go near eggs or baby animals; never touch young animals.

► If they look closely, pupils may find faeces, regurgitation pellets, feathers, possibly even evidence of fighting on the ground, shell fragments, half-eaten fruit or nibbled cones, nests, shelters, special smells, clues to the biological rhythm of a species, or signs of **animal migration**.

► The tracker teaches the pupils what each of these objects or traces could mean.

What do they tell us about the movements, feeding habits, reproduction, or territories of one or more species present in a given location? What about its relationship to the biotope?

Example:

The black rhinoceros (*Diceros bicornis*) sprays urine on the ground to mark its territory. Pupils will be fascinated as the tracker deciphers the information in these scent-markings to tell the animal's sex and age – even sometimes recognizing an identifiable individual!

Comment:

These things – sounds, noises, hoofprints, pawmarks, leavings and other clues – are all evidence of a species' existence; but although they make fascinating study material – graphic, arresting and somewhat mysterious – they are things done out of sight and frequently at some lapse in time. At this stage, therefore, it is important that the teacher takes the pupils back into the classroom, assembles the scientific information and the knowledge to be transmitted, and puts the various pieces of the puzzle together, locating each species in its proper place within the pattern of the ecosystem as a whole.

4. Sum up species information

After some time spent gathering source materials from books, photos, and (if the school is suitably equipped) from the Internet, and not forgetting the facts and anecdotes provided by the tracker or other local wildlife experts in person, the teacher gives the pupils an account of the main species in the local ecosystem.

► For each species, the teacher takes care to present both its general characteristics and the particular ways its morphology, physiology and behaviour are adapted to dryland ecosystems.

A. General characteristics of the species

The teacher explains a number of fundamental concepts:

• What is a **species**?

There are more than 1.5 million identified animal species on earth; the animal kingdom has by far the largest number of species.

Each species is unique: e.g. the golden jackal (*Canis aureus*).

Members of a species all show a common set of physical characteristics. They normally only reproduce with fellow members of the same species.

• Each species belongs to a **family**.

In scientific taxonomy, living organisms are organized in groups of increasing scope which indicate the degree of relationship between different species. Thus the golden jackal (*Canis aureus*) belongs to the Canidae family.

• What is a **mammal**?

The Canidae family belongs to the **class** of mammals (*Mammalia*).

Despite enormous differences in shape, size and behaviour, most mammals are covered in hair, and all the young suckle.

50

50. Vulture nest in an acacia shrub, Kenya
©Michel Le Berre

51. Vultures in flight, *Sierra Tarahumara*, Mexico
©UNESCO/Olivier Brestin

52. Griffon vulture (*Gyps fulvus*) at rest, *Cévennes*, France
©Michel Le Berre

53

54

• What does a particular species eat?
Is it a herbivore, granivore or **omnivore?**
Example:
In dryland areas, many omnivorous birds eat virtually anything they find that is edible: insects, seeds or twigs. This resource tends to make them better than other species at adapting to changes in their habitats.
Normally granivorous rodent species can in some regions adapt to eating halophyte plants with a hard salty skin. One example is the tamarisk gerbil from the Aral basin.
• What is a **predator?**
An animal that feeds on prey.
The teacher explains predation in the context of adaptation to the environment and the competition between species, or in other words the relentless struggle for survival.
It is a difficult way of life which often implies notions of strategy, as prey animals are constantly alert and will flee at the slightest sign of danger.
Many animals are predators.
Examples:
In Africa, snake-eating birds such as the secretary bird (*Sagittarius serpentarius*) spot their prey and then aim just behind the head in order to kill a venomous snake using a single powerful strike with its claw.
Scorpions in all dryland zones (those of the *Buthidae* family, for instance) grasp their prey in their claws and then kill it with the sting in their articulated tail. The largest species, such as *Leiurus quinquestriatus*, can catch lizards or small rodents.

• The teacher naturally moves on to discussing the idea of defence and the various ways that animals have developed for self-protection:
– Most try to flee;
Example:
Many rodents in dryland regions run on two legs to move faster and with less risk between one edible plant and another; one such is the marsupial rat in Australia.
– Other species use **mimicry** strategies to hide from their enemies by blending in visually with their environment.

Examples:
Australia's northern leaf-tailed gecko (*Phyllurus cornutus*) uses the natural **camouflage** of its skin to disappear against the tree trunks where it spends its day. It is almost impossible to spot, not least because of the cryptic colour of its eyes.
The Yemen chameleon (*Chamaleo calyptratus*), which is normally pale green with yellow stripes, can change colour to blend in with different backgrounds.

• The teacher also gets the pupils to think more generally about relationships among animals or between species.
– Some species are known as 'social animals'. They live together in groups, herds or clans. This makes it easier for them to find food, rear their young and spot predators by helping each other or sharing the tasks.
Example :
In a herd of giraffes, the mothers are helped by other members of the group to protect baby giraffes from attack; even unrelated giraffes will keep watch while the young drink.
– Animals have 'functional' relationships of many different kinds with other animal or plant species.
The next activity, devoted to the functioning of the ecosystem, will provide an opportunity to explain the particular relationships of zoochory, phoresy and commensalism between animals and plants (cf. Chapt. 1, act. 6, p.44).
For the moment though the teacher highlights other inter-animal associations, such as **parasitism** or **mutualism**.
Examples:
The camel tick sucks the blood of its host: an example of parasitism.
The relationship between the oxpecker and the gnu (or zebra) benefits both: this is known as symbiosis or mutualism.

53. Lions (*Panthera leo*), W National Park, Niger
©Michel Le Berre

54. Male giraffes in combat, (*Giraffa cameleo pardalis*), Niger
©Michel Le Berre

55. Scorpion (*Pandinus sp.*), W National Park, Niger
©Michel Le Berre

56. Spider (*Nephila clavipes*), New South Wales, Australia
©Olivier Brestin

55

56

B. Species' physical and behavioural adaptations in an arid ecosystem

The teacher explains that animals here face two big challenges:

- Withstanding the heat;
- Coping with the scarcity of water.

Over time, species have developed a range of avoidance or tolerance strategies so as to adapt to the heat and the lack of water in arid regions.

► First the teacher shows the **morphological adaptations** by which species deal with heat-related constraints:

- Hooves have become broader to facilitate movement on loose sand;

Example:

The very broad hooves of the addax antelope (*Addax nasomaculatus*).

- Mammals have developed hairy pads under their feet to act as insulation;

Examples:

These include the little Egyptian jerboa (*Jaculus jaculus*) and the Cape hare (*Lepus capensis*).

- Some animals have elongated ears to dissipate heat.

Examples include fennecs and elephants, which lose heat through their large ears. Other animals have long legs to keep their body a greater distance off the ground (ostriches, antelopes).

► The teacher then discusses the **physiological adaptations** of various species to cope with the scarcity of water:

- Most dryland animals get little to drink, or drink only at irregular intervals;
  - Some find water in the food they eat, for example gerbils and kangaroo rats, which convert the starch in seeds into water.
  - Others absorb moisture directly from the air through their skin, for example the thorny devil (*Moloch horridus*), a striking Australian lizard that looks like a dragon covered with spines.
  - Others can tolerate a certain level of dehydration: for example goats, mouflons and most of all, dromedaries, which store fat reserves in their hump. If the animal goes for long without drinking, these reserves are converted into water through lipid oxidation.
- Other species cope with dehydration by reducing the quantities they sweat and urinate.

Many rodents in various dryland regions produce highly concentrated urine and dry faeces, to limit water loss.

► Finally, the teacher explains species' **behavioural adaptations** to their environment, and the strategies they have evolved to protect themselves against heat and lack of water.

- One tactic is to take shelter, escaping from the heat in all manner of ways:
  - Since the dryland ecosystem often has wide temperature swings between night and day, many species bury themselves in their burrows during the daytime and only come out at night, when the air is cooler.

Example:

Like many other animals, the lesser Egyptian jerboa (*Jaculus jaculus*) makes a burrow very deep underground where it shelters from the daytime heat by blocking up the entrances with loose earth to keep in the moisture.

  - Other species, including many reptiles such as the officinal skink (*Scincus officinalis*, 'sandfish' in the vernacular), escape the scorching heat by burying themselves in the sand.
- A second strategy is to mitigate the effects of the burning hot ground:
  - Many species develop specific behaviour: the collared lizard (*Crotophytus collaris*) cools its feet by lifting them up, the sidewinder (*Crotalus cerastes*) throws one side of its body into the air as it moves sideways.
  - Other species opt for speed, quickly dashing or jumping from one spot to another.

This is a good occasion for the teacher to introduce the idea of the **convergent evolution** of rodents in different continents:

57. Darby wallaby (*Macropus eugenii*), Australia

57

Sketch of a jerboa (*Jaculus jaculus*)

For example, the pitchi-pitchi or marsupial rat in Australia, the American kangaroo rat, Asian gerbils and the Saharan jerboa all have a similar build, though they are not at all closely related: all have disproportionately large and powerful hind limbs forming a tripod for efficient running with a very long tail which helps them to balance as they move.

• Another behavioural response to extreme heat is to become lethargic:
Exposed to temperatures of 50°C, desert lizards and rodents can halve their cellular metabolic rate; they enter a state of **estivation**, a slowed-down condition analogous to hibernation.

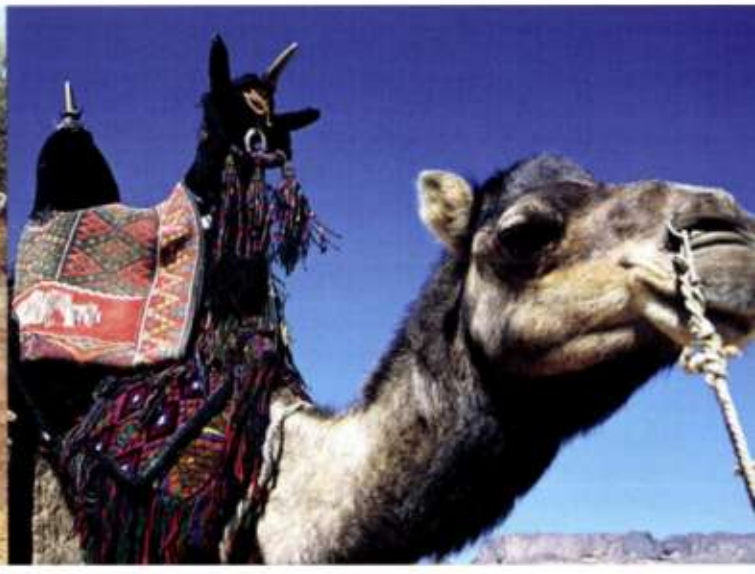
► The teacher concludes by looking at behavioural strategies used by species to cope with the lack of water.
There are ways in which certain species manage, despite everything, to moisten their bodies or even to drink by getting water from night-time mists, or from the damp walls inside their burrows, or recovering the moisture contained in exhaled air.
Example:
In the Namib Desert in southern Africa, tenebrionid beetles such as the 'fog-basking' beetle (*Onymacris unguicularis*) absorb the damp of coastal fogs by standing with their head lowered on dune crests. The moisture condenses on their bodies and trickles down towards their mouths, bringing life-preserving rehydration.

The teacher's presentation gives an idea of the astonishing adaptability of animal species, and the wide variety of responses they have evolved to the extreme living conditions of their various arid ecosystems.
► The teacher enriches these scientific facts with stories, if possible using varied, colourful documentation and incorporating the tracker's anecdotes.

5. Study an animal in the environment and take notes

►To conclude this activity, the teacher starts another phase of observing local species.

58. Nomadic pastoralists-herders, Sahel
© Thomas Schaaf

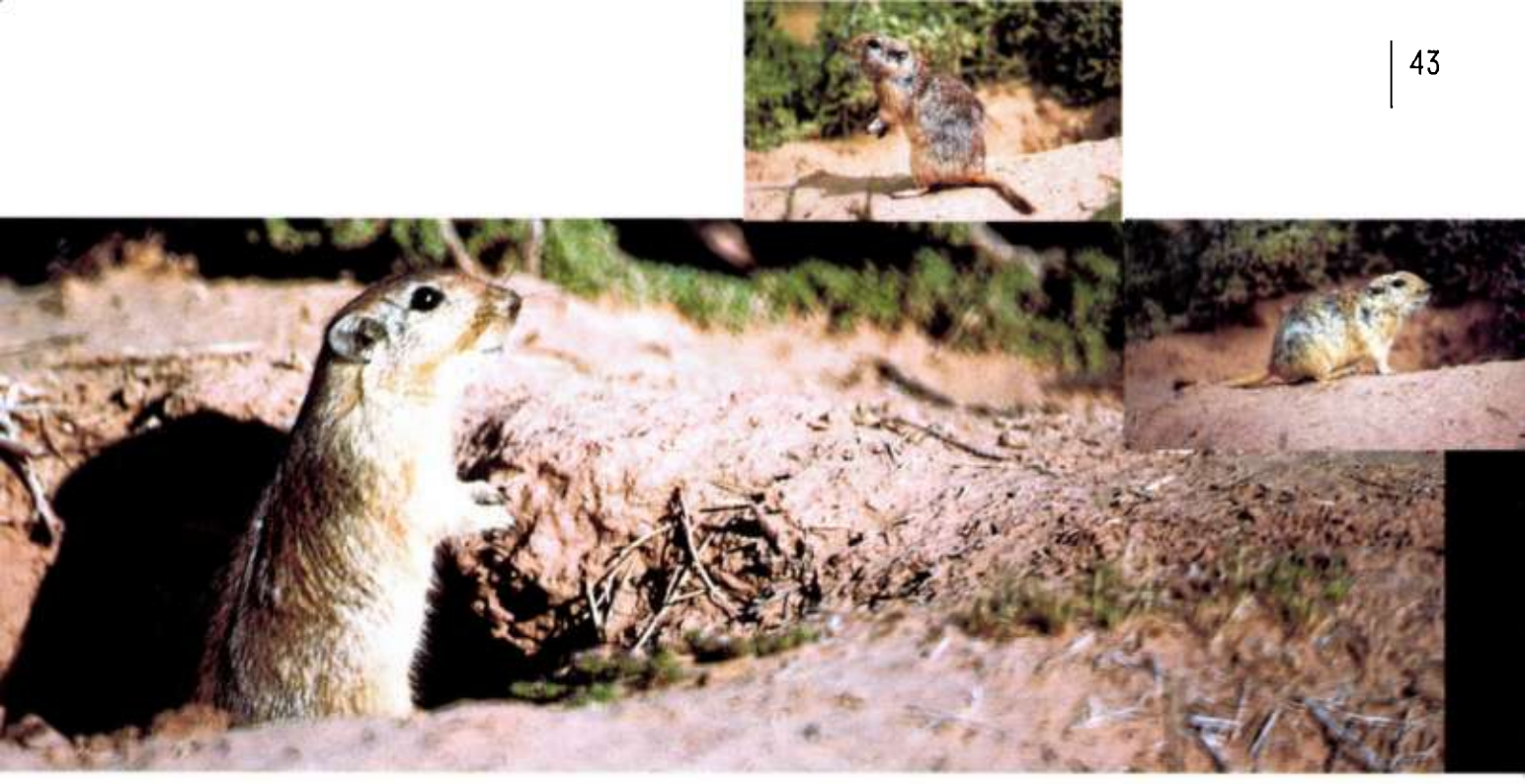


59. Dromedary with tuareg saddle, *Djanet, Tassili N'Ajjer*, Algeria
©Olivier Brestin

The pupils are encouraged to return to their everyday activities and embark on a study of a local species (domesticated or wild) in a real-life situation. Each pupil chooses an animal and observes it closely over several days.

► The pupil observes and notes its comings and goings; what it does, how it behaves in its habitat and how it reacts to events.
Ideally, the notes will also include drawings and quick sketches, though the idea is not to produce finished artwork but rather to capture a particular movement or behavioural gesture.

► In any case, the pupils' written notes should be a good descriptive reflection of how closely they have observed the animals.
Example: the dromedary.
– Its upper lip is split;
– Its pupil looks like an elongated, diagonal slit;
– It can carry heavy loads;
– It can carry loads in packs or people on saddles;
– It balks when forced;
– When not carrying a load, it goes off on its own to look for food;
– It prefers bushy vegetation to grass;
– When grazing it is constantly on the move, and ranges over a wide area;
– Thorns do not bother it: it grinds them with its powerful teeth (the inside of its mouth is insensitive);
– It likes to nibble fresh tree leaves, which provide water;
– It drinks noisily, a great deal in one draught;
– When it is healthy, well fed, and has drunk its fill, its hump is full and massive;
– When the hump is empty it is barely visible;
– The camel's broad feet and soft soles make it uncomfortable on stony ground and slopes;
– It has an ambling gait;
– It can move quickly on its long, slender legs (meharis);
– It is quite easily scared, and can take fright at the sight of a lizard...
– It produces highly nutritious milk, rich in vitamin C (precious in dry regions where fruit and vegetables are rare);



60. Gerbil (*Psammomys obesus*), *Goulimine* region, Morocco

– Its excrement, passed in the morning, is collected for fuel;
– What are the words used in the community to describe the animal, according to its age, sex, colour, physical shape and origin? (The Tuaregs have 100 or so words for camels, which shows how devotedly they revere the animal)
– Can a person be called a 'dromedary' or a 'camel'? What is being suggested? Indifference? Stubbornness? Spitefulness? Or something else?

6. Choose a species and write a story of the animal's life

► Back in the classroom, the pupils take it in turns to make a species 'speak' by making up their own stories.
The pupils each choose the species they want to represent, and think themselves into the part.
Example:
"I am a little jerboa. It is four o'clock in the afternoon, and unbearably hot outside: here I am, right at the bottom of my burrow. Fortunately, it is still cool here because it is so deep. The walls are damp; so sometimes, when the heat is too much for me, I collect a drop of water with my tongue as it seeps through or I brush against the wall to cool myself down…".

This exercise helps the pupils memorise what they have been taught. They can absorb information better by internalizing it, feeling it and expressing it with their own voice and body.
In telling these stories the pupils do not just mime situations, rather, they let their imaginations wander within the constraints of what they have learned, to really appreciate the animal's relationship with its biotope.
In what ways can the same environment be perceived and interpreted by different users? What are the rhythms by which they live, and what difficulties does each animal species face in its arid environment?
► As the stories succeed each other and the examples mount in number, different visions of the world are expressed through personification, showing how animal species use the environment in many different ways.

06 Mural of an Ecosystem

Level ★★★
advanced

Place
classroom and outdoors

Duration
4 sessions

Objectives

1. Discovery of the environment

Portray the ecosystem as a functional unit by making a big, colourful mural which features communities of plants, animals and micro-organisms interacting with their non-living environment.

2. Knowledge and comprehension

Use the mural to grasp the concepts and connections of ecosystem functioning, starting with the concepts of interdependence between species, trophic networks and ecological succession.

Methodology

1. Choose two areas in the surroundings with a high level of biodiversity

► The class scours the countryside nearby for two areas to represent the local ecosystem;
As the two should differ in their plant cover. The most obvious distinguishing feature of an ecosystem is its vegetation, which accounts for most of its biomass; plants determine the spatial structure of ecosystems and reveal its temporal patterns (seasons).
It is better to choose two areas fairly close to one another; ideally, one will be an area with natural vegetation (a natural ecosystem) and the other a cultivated area (a semi-natural ecosystem, partly governed by human activity).
Examples:
In Central America one area might be full of succulent plants such as *saguaro* bushes while the other has mixed vegetation including crops and nopal hedges.
In North Africa one could be bushy steppe with intermittent plant cover and the other an area with traditional crops – a palm grove, for instance.

2. Having chosen two areas to represent the ecosystem, locate them in the broader context of the landscape

It is important at this stage that the pupils see the two selected areas against the broader background of the entire landscape.
How do two parts of the ecosystem, characterized by the species that live there, fit into the large-scale landscape with its defining contours and formations?
► In this exercise the teacher gets the pupils to 'zoom out', either by finding a distant vantage point (or a commanding height), or simply by walking around and observing the landscape around them as they make their way from one area to the other.
How do the contours shape the landscape? Is the horizon clear, or is it cut off by rocky outcrops, foothills or mountains – and at what distance?
Are there escarpments? Slopes? A level plain? How do the different lines, levels and planes combine to make up the landscape?
► The pupils record their notes and drawings in their sketchbooks, and find their bearings: Which way are north and south? Where does the sun rise?

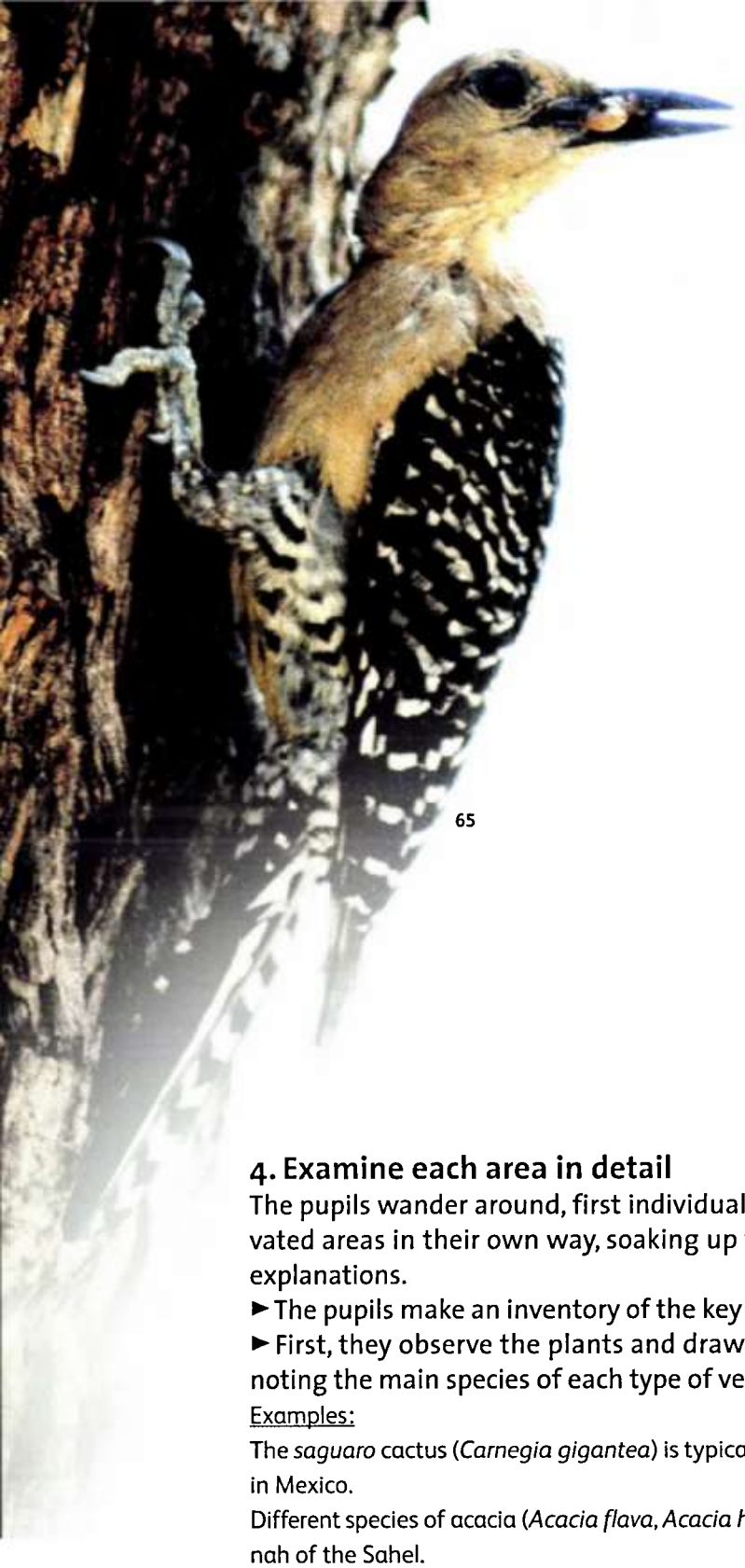
61 et **64.** Giant 'cardones' cacti and pampa grass (*Cortaderia selloana*), arid region of *San Pedro de Atacama*, Chile
©UNESCO/Olivier Brestin

62 et **63.** Giant 'cardones' cacti, semi-arid region of *Batopilas*, Mexico
©UNESCO/Olivier Brestin

Are the two areas that are to represent the ecosystem on a plain, or nestling beneath an escarpment?
Are they protected from the wind by hills? Are they protected from too much sun?
Are they humid areas? In what form is water present, and how much?
These are all important points to note, and will be used for preparing the overall layout of the mural.

3. Draw a silhouette of the landscape as background for the mural

► The pupils use a large sheet of paper, opened out and attached to the wall.
► Using the information gathered while viewing the landscape, they draw a background for the mural to provide a setting for the portrayal of the two selected ecosystem areas.
This silhouette of the landscape does not necessarily have to be realistic.
► The pupils sketch features of the relief and the skyline to act as a backdrop and give an overall sense of unity to the ecosystem represented: this must not be reduced to one or more separate units but seen as a whole, a complex network of interrelating ecosystems in the landscape.
Onto this background the pupils superimpose detailed, close-up, frontal representations of the two ecosystem areas; they look like two enlargements or magnifying glass images of the ecosystem.
The reason for choosing two areas (natural and semi-natural) is to show how the ecosystem takes on a different form in different parts of the landscape.
► For this purpose, the teacher begins by taking the pupils outside to inspect the two chosen environments.



65

66

67

4. Examine each area in detail

The pupils wander around, first individually and then as a group, observing the wild and cultivated areas in their own way, soaking up their discoveries. Then come the teacher's hints and explanations.

► The pupils make an inventory of the key species that make up the biocenosis of each area.

► First, they observe the plants and draw them quickly in their sketchbooks, recognizing and noting the main species of each type of vegetation.

Examples:

The *saguaro* cactus (*Carnegia gigantea*) is typical of the cereus cactus bushes that grow in the Sonoran desert in Mexico.

Different species of acacia (*Acacia flava*, *Acacia hamulosa*, *Acacia tortilis*) are typical of the dry wooded savannah of the Sahel.

► The teacher encourages the pupils to talk to older members of the community who know the local environment well.

Which companion plants cohabit with the main species they have already noted?

► With each other's help and the teacher's guidance the pupils learn how to identify and recognize species in their natural habitat.

Examples:

The *ocotillo* with leafy stems (*Fouquiera splendens*) and yuccas (*Yucca brevifolia*) are also part of the phytocenosis of the *saguaro* (*Carnegia gigantea*). Some sub-shrubs and other companion plants provide the shelter necessary for the *saguaros* to germinate.

► The elders are well aware of the connections between different species; their lively anecdotes can introduce the pupils to the inhabitants of the various flora.

Examples:

The stem of the *saguaro* gives shelter to many animals: for instance, the Harris's antelope squirrel (*Ammospermophilus*) and the northern flicker (*Colaptes auratus*), whose holes are reused by various small owls, such as the elf owl (*Micrathene whitneyi*).

When one living organism benefits in this way from the shelter of another without harming or disturbing it, this is known as **commensalism**.

Birds such as the gila woodpecker (*Melanerpes uropygialis*) eat the fruits of the *saguaro*, which contain huge numbers of seeds that they disseminate without digesting them, thus helping to disperse and preserve the species: a process known as **zoochory**.

►The elders tell the pupils which areas are suitable habitats for particular species; they take them to look at both sheltered and humid microenvironments, and give them some clues about orientation, surface water sources and where the **groundwater** lies.

The pupils note this valuable information in their notebooks, and make the connection between the resources and conditions of the local environment and the species it harbours.

Examples:

The *saguaro* prefers warm, south-facing slopes: it cannot survive 24 hours of frost.

Bulb and tuber plants such as *Iris sisyrhynchium*, a small iris from the arid Mediterranean regions of north Africa, huddle into small depressions where water accumulates storing it in their storage organs.

65. Gila woodpecker (*Melanerpes uropygialis*), *Satevo* region, Mexico
©UNESCO, Olivier Brestin

66. Ocotillo or coachwhip (*Fouquiera splendens*), *Cuauhtémoc* region, Mexico
©UNESCO/Olivier Brestin

67. Yucca, *Urique* region, Mexico
©UNESCO/Olivier Brestin

68. Turtle-dove, *Satevo* region, Mexico
©UNESCO/Olivier Brestin

69 et **71.** Flowers and leaves of the ocotillo, *Cuauhtémoc* region, Mexico
©UNESCO/Olivier Brestin

70. Ocotillos (*Fouquiera splendens*), *Cuauhtémoc* region, Mexico
©UNESCO/Olivier Brestin

68

69

70

71

5. Put ideas together, on the basis of observation in the field

Before the mural is begun, the teacher presents the ideas that emerged in the earlier survey of the terrain, but now in organized form.

A. Interaction between living species and the non-living environment

► The teacher may draw diagrams of certain situations on the blackboard to spark the students' interest;

► The teacher illustrates the following points:

• Each of the two selected areas supports an ecosystem, a dynamic network of one or more communities of living organisms and their non-living environment.

• The different species affect each other in various ways, and depend on **abiotic** or non-biological factors such as the soil and climate.

• These abiotic factors are the resources from the environment: water, light, (soil) nutrients and space as well as the conditions created by temperature, wind, rain and climate change.

B. Interdependence between species and trophic networks

► Here the teacher may draw various diagrams, including a simplified food chain.

Arrows are used to represent the links between living organisms that are eaten by other organisms (cf. diagram, p. 21). It is understood that the arrows indicate the direction of matter transfer, not that of predation.

Example:

Grass ► Antelope ► Lion

► These are some points that the teacher might choose to mention:

• Most species eat a variety of foods and are part of several food chains, which form a **trophic network**.

• The various food chains begin with plants, which are **producers**. Plants use the radiant energy of the sun to convert atmospheric carbon dioxide into organic molecules thus producing proteins and sugars in plant matter used by other organisms (see Chapt. 2, act. 3, p. 80).

• Other species in the food chains are **consumers** (humans and other animals), which survive by eating producers and other consumers.

It is important not to forget the **decomposers**, which feed on dead organic matter and recycle its nutritious elements.

72. Crops among the palms, Tunisia
© UNESCO-MAB

73. Crop irrigation from a well using animal traction, *Iférouane, Aïr*, Niger
©Michel Le Berre

• Food dependencies ('A eats B') are not the only forms of interaction.
In addition to commensalism, there is zoochory, the dispersal of fruits and seeds by animals. There is also **phoresy**, the process by which some animals (acarids, insects, molluscs) are carried by other animals from one location to another.

C. Ecological succession

The teacher may produce a chronological diagram of a developing ecosystem. An explanatory diagram of this sort, presented in an interesting way with examples, introduces the notion of time in the ecosystem.
► The teacher illustrates the following points:
• When an ecosystem is destroyed by a hurricane or forest fire, the natural environment gradually re-creates itself. In a process known as **ecological succession**, it goes through different stages until a stable biocenosis emerges.
• Where the soil is bare, wind-borne seeds fall and germinate: in the right conditions, so-called 'pioneer' plants can thrive without competition from other species.
• Bigger plants then join these pioneers and start to dominate them. Competition for light intensifies the preponderance of one species over another, in an upward race for a 'place in the sun'.
• In dry areas, plant cover is sparse; but different storeys of vegetation – low-growing plants, sub-shrubs and bushes – can still be found, even in plant formations such as scrubland or dry savannah.

6. Make the ecosystem mural

After this explanatory stage, the class sets about making the mural, first pencilling in the main outline of the cultivated and natural vegetation areas on the mural background.
► The pupils use any medium available: coloured crayon, soft lead pencil, pastels, watercolours, poster paint or powder paint.
► The task of drawing is parcelled out among the pupils, and each then colours in or paints the portion he or she has drawn.
► The pupils use colour as a fundamental tool for creating the mural because it enables them to illustrate the ideas that emerged in the earlier discussions with the teacher.
A colour-coded representation of the storeys of vegetation, for instance, helps to illustrate the broader notion of ecological succession, mentioned earlier.
Example :
Traditional crop-growing in North African or Arabian palm groves is organized in storeys: each storey creates a microclimate which enhances growing conditions in the one below. Colours make it possible to differentiate

74 75

the storeys and show their importance: the palm trees of the top storey shade the smaller fruit trees: lemon, orange, fig and olive. These small fruit trees in turn protect lower-growing crops such as tomatoes, peppers, carrots, wheat, barley, alfalfa, henna and maize.

► The pupils pick out the shapes and plants in colour, using a coloured pencil or a fine paintbrush.

► They also use colour to indicate competition between species with similar needs, and between plant species that need access to water.

Example :

The pupils use two corresponding colours on the mural to represent the plant cover of a semi-desert with shrubs: Central Asia, for instance, where grasses and sub-shrubs like *Ephedra przewalskii* partially cover the ground. In late summer and autumn rain is rare, the grasses are dry (pale yellow in colour), and sub-shrubs are ablaze with coloured fruit (red).

Here it is worth using a 'window'* to show how the balance of power between the colours is reversed as the seasons change: the green of the grass predominates as soon as the rain returns in spring.

So, depending on the situation, some species will predominate over others.

► To show the alternating predominance of one species over another and the changing coloration of the landscape, the pupils use 'windows' in the mural for portraying an alternative situation, or one which changes over time, or an extra detail, or something in close-up, putting what they want to 'magnify' in a separate, clearly drawn circle.

The use of such a window, with a connecting line drawn to the main picture, can for example illustrate the changing colour of plants and competition between species in different seasons, thus suggesting the dimension of time in the ecosystem.

► The pupils also use the design (set into a window) to bring out details such as the importance of a species' morphology in its interaction with the environment and other species.

Example :

Ephemerophytes with wide-ranging superficial roots designed to absorb the meagre amounts of precipitation happily coexist with species such as **geophytes** or bulb and tuber plants (irises, tulips, onions) that have underground storage organs or with species that have very deep roots, such as acacias.

* Windows are drawings that appear in the margins with or without annotations and portray a detail or a close-up of a particular element. They mostly appear in a circle with an arrow to the main picture.

► Finally, the whole class adds the various animal species to the mural, each in its particular habitat. Part of the watering hole is shown as a cross-section, or in a magnifying window. The pupils draw in the main animal species that live there: fishes, amphibians, insects. Who eats who? Animals that feed on other living organisms are represented, as well as those that get eaten. The animals that gather near the watering hole are included as well.

Example:

Water-carrying birds such as the *pin-tailed sandgrouse* (*Pterocles alchata*) in Africa use their breast feathers like a sponge to carry water for their chicks. They can be drawn in this way on the mural, giving water to their young.

► The teacher makes sure that the representations of the two typical areas match and echo one another in the mural, showing how in each different part of the landscape the ecosystem functions through the resident species which inhabit that particular part.
The overall impression is of a mural that is inhabited and teeming with life. The idea is not so much to capture the details of the animals' build, posture or characteristic movements (for sketching from life is not easy), but to bring to mind their existence and the fact that they belong to the ecosystem by including them in the mural.
► What the class is aiming to do is to show the hidden side of the ecosystem by specifically including an example of each of its inhabitants, as if all the species had become visible and identifiable.
► Different interactive synergies between animals may be highlighted through the use of windows: One window illustrates the interdependence between animal species within the food chain; another the idea of the plant cycle which involves flower pollination (bees, birds), seed dispersal (birds) and plant germination.

This provides a way of conveying the idea of synchronization among the ecosystem's various elements: a dynamic web or a working, constantly evolving 'factory'. It adds a new layer of understanding: the time-related aspect of the ecosystem and its sequences of events. This is explored in the following activity.

74. *Pancratium sp.* (geophytes), W region, Niger
©Michel Le Berre

75. Crocus flowers (geophytes), W region, Niger
©Michel Le Berre

76. Plant with succulent leaves *Malephora crocea*, Chile
©UNESCO/Olivier Brestin

77. Flowers of aizoaceae or fig-marigold family (*Carpobrotus sp.*), *Bookmark* Biosphere Reserve, Australia
©Michel Le Berre

76

77

07 Biodiversity Playlets: Links in the Web of Life

Level ★★★
advanced

Place
classroom

Duration
5 sessions

Introduction

By 'biodiversity' (short for 'biological diversity') we mean the entire range of life forms on Earth. It encompasses the total number of living species (animals, plants and micro-organisms) on the planet as well as the natural characteristics specific to each species. It makes up the web of life of which we play an integral part and on which we are totally dependant.
Each element – a particular species or one of its natural characteristics – forms a link in the chain of life and it is connected to other links that make up the web. Each element *influences* others and is itself *influenced*; all the elements are interdependent: each one acts and is acted on.
This activity will enable the pupils to clearly picture in their minds and thus appreciate that a 'gap' in the web of life not only implies that a particular species has disappeared or that it no longer exists but that a link has been 'skipped'. This implies a 'gap' or a discontinuity in the whole set of interactions among the various elements of the biodiversity in question. It indicates that the behaviour of one element has an effect on the entire system; the links fall apart while the 'gap' grows bigger.
If one species of bird disappears from an ecosystem, that will put an end to its role in **pollination** and **seed dispersal**, which the bird would carry out in the course of its everyday activities.

Objectives

1. Knowledge and comprehension

By imagining several scenarios and sketches that bring to life the consequences of a species' disappearance, the pupils come to appreciate the impact which a loss of biodiversity has on the ecosystem.

2. Aptitudes

Through mime and role-playing, pupils internalize and adopt responsible ways of thinking and behaving, for the benefit of biodiversity.

78. Oleander flower, (*Nerium oleander*), *Ihérir*, Algeria
©Michel Le Berre

79. Bumblebee gathering nectar
©UNESCO-MAB, R. Bill

80. Spontaneous palms and volcanic dyke, *Aharhar*, Algeria
©Michel Le Berre

Methodology

1. Choose a key species in the ecosystem

► Working in groups, the pupils choose a species they have already identified in the ecosystem: a plant, animal or insect whose characteristics they have studied in the previous activities.

► The teacher helps them to choose a species which carries out several functions within the ecosystem (food chain functions, plant **germination**, seed dispersal, pollination, or replenishing soil nutrients). These species will exemplify several types of interdependence with others: mutual dependencies without which the ecosystem would not be the same.

2. Imagine scenarios of how the ecosystem might evolve if this species disappeared

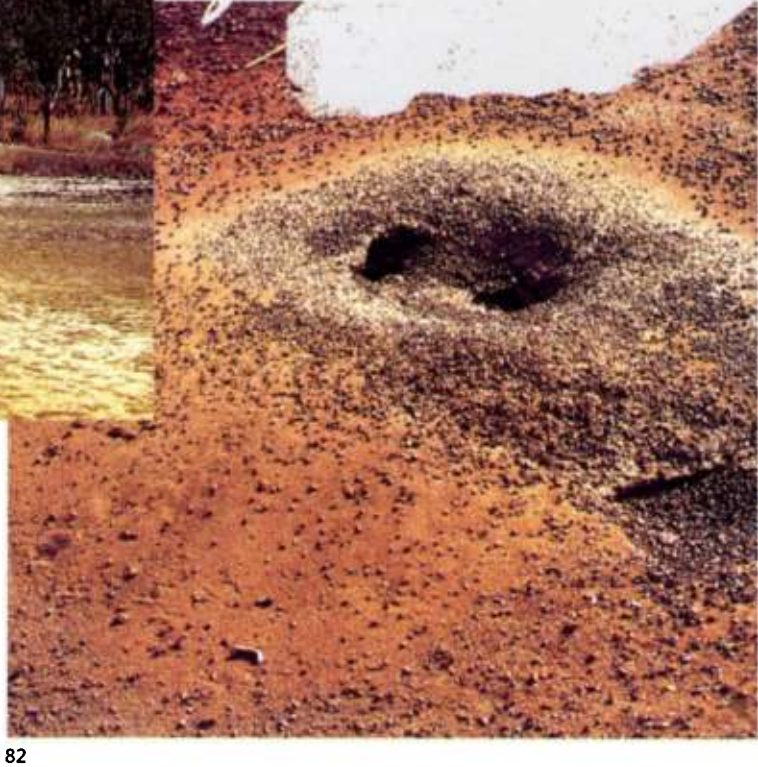
► In class, the pupils discuss what happens within the ecosystem when a living organism disappears. They visualize and describe the sequence of events, taking turns to help construct scenarios. This story-making is a live process: everyone has an anecdote to contribute. The teacher is there to get the progression of ideas back on track if necessary.

Example scenario n°1:
What happens to cereus cactus bushland in Mexico if the desert ironwood (*Olneya tesota*) disappears, or one of the other shrubs which cohabit with the *saguaro* (*Carnegia gigantea*)?
• There is no longer a leaf-fall from these shrubs in the dry season, which used to add nutrients to the soil.
• The shrubs' dense branches no longer provide the shelter needed for the *saguaro* to germinate.
• Their roots no longer retain the soil during **huaycos** – 'washouts' or flash floods.
• The insects, rodents, reptiles and birds which feed on the shrubs' foliage, stems or seeds no longer find the food they need; their numbers fall, or they disappear altogether.
• This in turn affects predators such as the cactus ferruginous pygmy-owl (*Glaucidium brasilianum cactorum*), which preys on reptiles, or the coyote (*Canis latrans*), which eats rodents.
The impact of these changes is damaging to the whole ecosystem; the *saguaro* itself is threatened, especially if the seeds can no longer be dispersed in granivorous or omnivorous bird droppings or by being carried in the fur of small mammals.

Now the *saguaro* cannot germinate, nor can it grow and develop under these conditions. The whole balance of the ecosystem is compromised.

►The pupils imagine similar scenarios concerning the disappearance of detritivores: ants, termites and some darkling beetles which are relatively common in arid regions.

81



82

81. Magnetic termite mounds, Northern Territories, Australia

82. Ant nest, W region, Niger

83 and **84.** *Mallee* views,
Bookmark Biosphere Reserve, Australia

Example scenario n°2:
What would happen in the Sahel if dung-beetles or other scarabs were to disappear?
• These organisms play an essential role in the nutrient renewal cycle that keeps the soil fertile in the dry Sahelian savannah. If they were to disappear:
– They would no longer recycle the huge quantities of excrement left by big herbivores or domestic livestock, crumbling and separating out the coarse droppings on which they feed;
– They would not prepare this organic matter for its final decomposition by micro-organisms and decomposers, leading in the end to the 'assimilation' of the nutritious mineral elements by the ecosystem.

Example scenario n°3:
What if the ants disappeared from bush landscapes such as the Australian *mallee* shrubland or the *Gran Chaco* of northern Argentina?
• The ants would no longer play their part in regenerating the soil by concentrating nutrients in particular locations. For instance, they carry chewed and regurgitated leaves to their **fungus beds** to provide an ideal **compost** for fungi to grow.
• They would therefore no longer promote the growth of fungi, nor would there be compost in these particular areas to be broken down by decomposers (including fungi), which recycle the nutrients contained in dead matter by releasing mineral elements (nitrogen, phosphorous, magnesium, and potassium) into the soil.
• Ants' nests would no longer provide sites for the rapid succession of vegetation from grasses or **succulent plants** to woody plants.
Again, the equilibrium of the ecosystem would be under threat.

3. Act out a little three-scene 'ecosystem drama'

► The teacher gets the pupils to write synopses of the chosen scenarios, and then to act out the situations in question.
The class is split into groups taking turns as actors and audience.
Each group works out a sketch based on a synopsis, preparing signboards (written or drawn) beforehand.
► The acting group mimes the situation, using the signboards now and then to clarify: the boards tell the spectators who the actors represent ('we are omnivorous birds'), or what is happe-ning in the environment ('the drought continues' for example, or 'pesticides pollute the soil').

► The action takes place in three scenes:

Scene 1:

► The actors begin by demonstrating how the morphology and behaviour of a particular species are finely-tuned and well adapted to the harsh conditions of an arid ecosystem.
The pupils may mime situations involving species whose characteristics they have studied and they improvize by bringing into the sketch what they have previously learnt.
Examples:
The sand lizard of the Namib Desert literally swims in the sand to escape the heat.
In a prolonged drought the Mongolian gerbil can widen its range of foods to include all sorts of plant parts (leaves, stalks, seeds, roots, and the bark of woody plants).
Ants use wind-borne material to create their own specific ecosystem in places with no vegetation.

Scene 2:

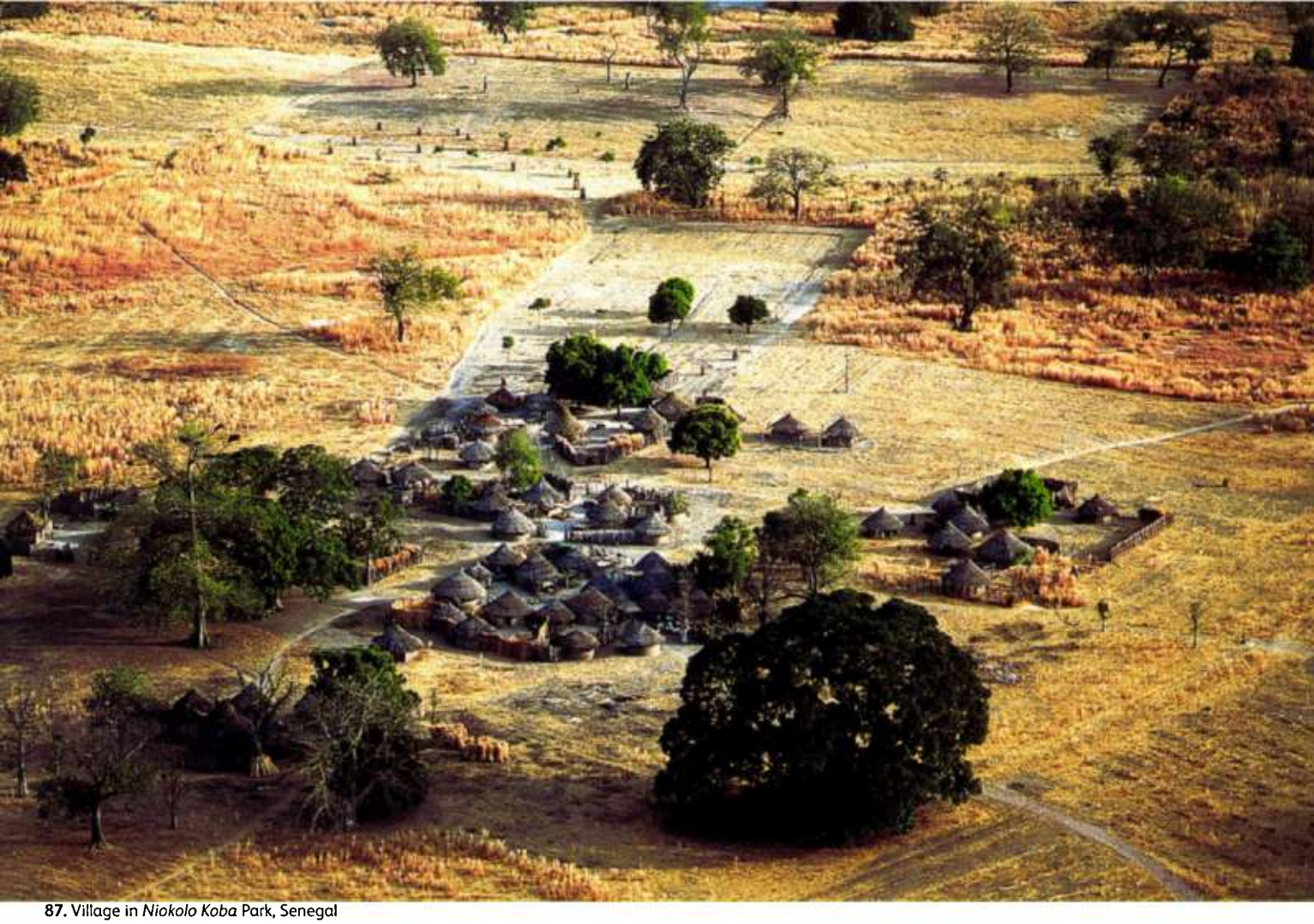
► The pupils then explain to the audience that this species is endangered, or dying out.

Scene 3:

► The actors mime the sequence of effects that follows the disappearance of the species. In this way some of the pupils' observations and distinctions are made clearer:
• If the species in question (a rodent, for example) is eaten by many other species, then the consequences of its disappearance are greater than if it is only eaten by one other species, because several other species will in turn become scarce or disappear altogether.

85. Sahelian farmer
© UNESCO-MAB

86. Market gardening along the river bank, W region, Niger
©Michel Le Berre



87. Village in *Niokolo Koba* Park, Senegal
©Yann-Arthus Bertrand, *La Terre vue du Ciel*, UNESCO

• Specialized organisms which only eat one kind of food, such as larvae that are associated or dependent on succulent plants, are under greater threat than those with a varied diet, such as omnivorous birds.
Depending on the situation, the pupils act out the behavioural differences between one species and another.

► Finally, they act out the impact of the species' disappearance on the ecological functions which are no longer carried out:
Whatever their characteristics, all species are indispensable: they perform functions that originate from the interactions between species (for example regulating population size, seed dispersal), and provide valuable services for the smooth functioning of the ecosystem.
Humans cannot replace these functions when species disappear: the pupils will be acting out the disappearance of some vital ecological functions.
They portray, for instance:
– The invasion of pests (migratory locusts, aphids) in the absence of their predators (chameleons or ladybirds);
– The decline in pollination by bees;
– The lack of maintenance of soil fertility, normally carried out by ants and termites;
– Floods and strong winds that are no longer held back by trees and bushes with their deep roots and their foliage (such as the wild olive, cypress and holm oak in the Mediterranean ecosystem).

► Inspiration sparks inspiration; the drawings or words on the sign boards highlight the message of the mime and demonstrate how the ecosystem can break up when essential ecological functions disappear.
The little ecosystem drama gradually becomes quieter and less animated; life fades away, until there is total silence.

89

88. Crops, *Sidi-Bel-Abbès* region, Algeria
©Olivier Brestin

89. Herders, *Sidi-Bel-Abbès* region, Algeria
©Olivier Brestin

90. Pomegranate and dates at the market, *Tatahouine*, Tunisia
©Michel Le Berre

90

91

92

93

94

91. Stall holder selling fruits and vegetables, *Sidi-Bel-Abbès* region, Algeria
©Olivier Brestin

92. Stall holder selling vegetables in *Ghardaïa* market, Algeria
©Olivier Brestin

93. Watermelons on the stall, Uzbekistan
©Michel Le Berre

94. Spices at *El-Oued* market, Algeria
©Olivier Brestin

4. Bring things together and draw conclusions

► The teacher takes advantage of the silence and the pupils' anticipation to bring out certain aspects of the three-scene drama that ends with the disappearance of biodiversity:

• A unique natural heritage is lost: drylands are extremely important for biodiversity on a large scale as the home of unique species that demonstrate close adaptation to their environment. Besides, drylands are home to many drought-resistant and drought-combating species.

• There is a clear causal relationship between loss of biological biodiversity and ecosystem destabilization because living dryland species have become more adapted than they have become diversified, playing an active part, often at several levels, in the ecosystem.

Here more than elsewhere, there is a danger that upsetting a species' equilibrium and allowing it to disappear will destabilize the ecosystem itself. The fragmentation of the ecosystem, followed by its degradation, leads to desertification – the most serious threat to biodiversity.

• Humans themselves are dependent on the conservation of biodiversity. The document entitled *Sustaining Life on Earth*, published by the Secretariat of the **Convention on Biological Diversity**, puts it this way: "The loss of biodiversity often reduces the productivity of ecosystems, thereby shrinking nature's basket of goods and services, from which we constantly draw".

It is biodiversity that provides the resources (with the coexistence of plants and animals), which are essential for human communities living in agricultural and arid regions. Another network of interdependence!

Furthermore, the greater the variety of resources available to people, the better their chances of surviving climate-related difficulties and the uncertainties of the environment.

5. Assess the impact of human activities on biodiversity

What role do humans play in an ecosystem?

► The pupils investigate the underlying causes of one or more threats to biodiversity from human activity.

► By thinking and discussing with the teacher, they learn how loss of biodiversity through the disappearance of species and depletion of genetic capital is largely caused by human intervention.

They list various harmful effects and adverse factors in arid regions. These include:

• Over-exploitation of the soil, which as a result becomes depleted or exhausted (not enough crop rotation; monoculture; excessive ploughing and digging).

• Conversion of natural plant cover (such as savannah pasture) into land for cultivation and human settlement (species' natural habitats are taken over for farming to meet the needs of a constantly growing population).

• Intensification of stockbreeding and overgrazing; herd pressure on vegetation (especially in the dry season, when trees and fodder bushes represent up to 60% of the diet of cattle) and trampling of the soil.

• Increasing use of certain tree species for building and tool-making.

• Worsening deforestation from the use of firewood as households' main energy source.

• Destruction of species (plants and animals) by overuse of soil-polluting insecticides and pesticides for intensive agriculture.

• Disappearance of wild fauna, leading to the isolation and fragmentation of plant populations. In lands where animals continue to survive they provide the main form of seed dispersal.

• The reduction of genetic diversity in traditional local crops, which are essentially made up of sorghum, millet and **legumes** such as peas or beans.

► The teacher sums up:

All of these associated factors lead to the destruction of the plant cover, a drastic reduction in the number of animal species and the depletion of the genetic capital.

6. Act out behaviour and actions beneficial for biodiversity

► Rather than simply blame the reduction of biodiversity on human activities, the pupils think about what should be done to avoid such a situation.

► They gather information and develop scenarios of behaviour and actions that are beneficial for the ecosystem.

► No doubt with a certain amount of jubilation, they play the role of responsible adults and may choose to represent some of the following situations:

- A farmer establishes a system of aeration and fallow on his land;
- Another, helped by scientists, analyzes a wild natural area and compiles an inventory of species living there before deciding not to farm on it;
- A shepherd gets rid of some of his livestock and invests his energy in finding an additional source of income (handicrafts, for example);
- Another decides to preserve the sparse resources of biomass generated by the rain and finds substitute foods for his animals (fodder from elsewhere, purchased cereals);
- A rich palm tree grower takes the risk of using fewer herbicides and pesticides

and allowing an ecosystem to spontaneously develop on part of his cultivated land. What do the fruits that continue to grow there taste like?

- If the area is close to water, are there fewer harmful and **invasive species**, such as water hyacinths (*Eichhornia crassipes*), as their natural predators return and eliminate them?

In this context, the teacher explains that a species such as the water hyacinth is considered by humans to be 'harmful' even though its spread, associated with its status as an invasive exotic species, is in fact due to its displacement by humans to a habitat that is free of its natural predators.

Chapter 2

Maintaining Plant Cover

01 Steps towards Understanding Plants and Flowers

Level ★
easy

Place
classroom and outdoors

Duration
2 sessions

Objectives

1. Discovery of the environment

The pupils begin with a sensory exploration of the plant life in their surroundings; then they work with colour to study and identify angiosperms (flowering plants) in particular.

2. Knowledge and comprehension

The pupils get an understanding of the role of flowering plants in the reproductive cycle of species, and discover their fundamental importance in the maintenance of plant cover.

Methodology

1. Explore the world of plants using all the senses

The teacher gets the pupils to investigate plant life using all five senses, preferably during the wet season:

► Depending on the plant formations that make up the local environment, the pupils walk through the tall grass (dry grassy savannah), feel the texture of leaves with their fingers, rub and stroke the plants, discover the bark of trees and shrubs, or stand underneath a tree looking up into the crown and taking in everything they see.

► They listen to the sounds of vegetation in the wind: branches creaking (cypress, pine, baobab), foliage rustling.

► They notice how the grasses sway in the wind, and stand under different kinds of tree during the rainy season to listen to the noise of the rain. What does heavy rain sound like?

1. Various flowering plants of which *Calendula*, Morocco

2. Flowering of statice or wavyleaf sealavender (*Limonium sinuatum*) on red reg, Morocco

3. Flowering of various wild plants, *Lella Setti* plateau, *Tlemcen*, Algeria

Like a drum? How does the sound of the rain vary with the leaf size and texture of the plants it falls on?

► The teacher encourages the pupils to use their senses of smell and taste. They sniff, savour and breathe in the smell of various plants.

They note the smell of different flowers; they pick tiny bits of conifers and **aromatic plants** and crush them under their noses to release the scent.

Examples:

The scaly leaves of cypresses such as *Cupressus sempervirens* or the needles of the Aleppo pine (*Pinus halepensis*) in Egypt, Libya and Mauritania.

The seeds, leaves and umbrella-shaped flowers of dill (*Anethum graveolens*), which grows wild in the Near East.

► The pupils make collections of scents, even ephemeral ones, by putting their samples in boxes or small bottles. Then they try recognizing these samples with their eyes shut.

► The same exercise can be done with the taste of fruits and seeds from wild plants – taking the necessary precautions, of course: the teacher must know how to distinguish edible plants from poisonous ones.

Examples:

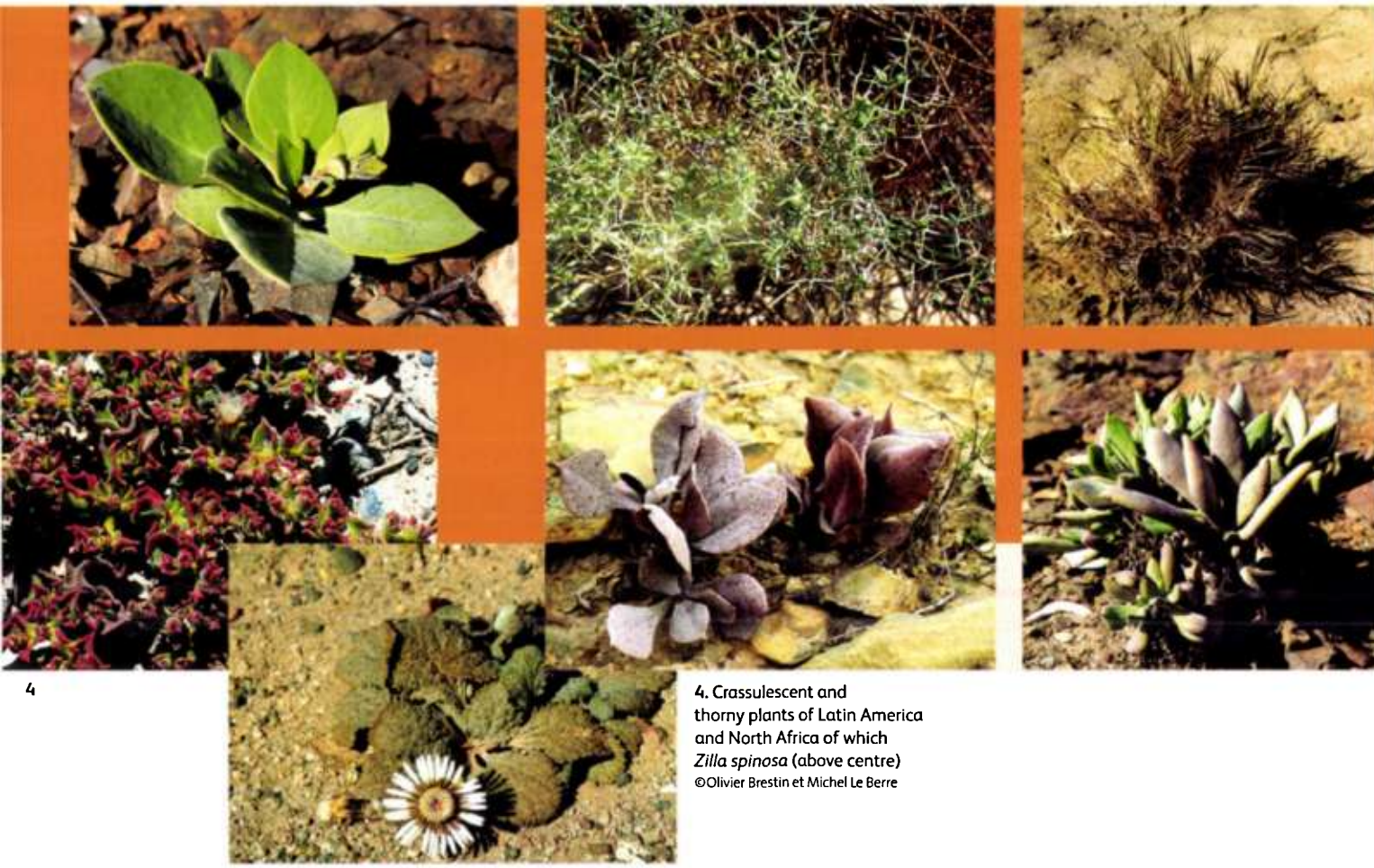
The edible fruit of the mesquite (*Prosopis chilensis*) in Mexico and Chile.

The often tasty fruit of the baobab (*Adansonia digitata*) in the Sahel.

2. Make tactile boards from collected items

► The pupils arrange the leaf samples they have collected side by side, or lying across or on top of each other.

They learn how to keep them together using thorns (easy to find in dry regions) or a drop of glue. Working in groups, they put their interwoven plants on pieces of cardboard to stop them falling apart.



4

4. Crassulescent and thorny plants of Latin America and North Africa of which *Zilla spinosa* (above centre)

► Now they use their sense of touch to identify the different material and texture of leaves:
• there are flat leaves, needles, scales and ribbons.
• leaves can be smooth, soft, thick, hard, crassulescent (fleshy), hairy, prickly, sticky.
► From a wide range of seeds, either visible (grasses) or from fruits (drupes or dry fruits such as achenes, capsules, siliques or pods), the pupils make tactile boards by gluing fruits or seeds onto cardboard. In this way they come to appreciate the variety of materials, textures, sizes and colours of the items they have collected.

Example:

The typical fruit of leguminous plants is a pod. Pods can be downy, tough, tender, big or small, depending on the species (beans, broom); there are also obvious differences among species within a genus (the pod of *Acacia tortilis* looks quite different from that of *Acacia nilotica* or *Acacia albida*) (cf. sketches p.72).

► When arranging the items on the board, the pupils may make shapes using the seeds and fruits or arrange them in chromatic order, from the lightest to the darkest (when the colours stand out).
► This display board of seeds and fruits can be used to introduce the different stages of the plant reproductive cycle:
The fruits come from a flower. When the flower has been fertilized by pollen from stamens, the pistil (female organ) becomes a fruit. Inside the fruit are the seeds.
► At this stage, the initial sensory exploration of plants and their constituent parts is concluded by the teacher suggesting that the class concentrate on flowers, or rather flowering plants, angiosperms: their flowers attract and delight us, and these plants make up 80% of plant species, even in arid regions.

► The teacher explains:
Flowering plants grow in many differents forms: shrubs, climbers, herbaceous plants, soft grasses and stems; they have conquered every environment on the planet, and in particular have adapted to the difficult living conditions of arid ecosystems (see Chapt. 3, act. 3, p. 78).
There are fungi and other kinds of plant living in arid regions, as well as flowering plants: lichens, mosses and **gymnosperms** (conifers and cycads).

3. Focus on flowers by working on colour

The teacher should choose the rainy season for this stage of the activity: this is when it is easiest to study flowers.
► The teacher guides the pupils in discovering flowers by choosing specimens with broad corolla or, if they are not available, flowers with colourful open petals.
The pupils concentrate first of all on the locally available 'simple' flowers: ones which grow individually on a peduncle and have an obvious, fully opened corolla.

► The class studies typical flower anatomy, starting with four elements necessary for fructification:
Two essential elements, the pistil (often composed of several carpels, or female sexual organs) and the **stamens** (the male sexual organs), and two other parts, the **calyx** (the outer ring of sepals that protects the flower in bud) and the **corolla** (the inner ring, of petals), the sign of a flower in bloom, with the pistil and stamens at its centre.
Examples:
Species that could be studied include poppies (from the *Papaveraceae* family), such as the prickly poppy or Mexican poppy (*Argemone mexicana*) found in Chile, portulaceous plants (*Portulacaceae*) or mallows (Malvaceae) such as *Calandrinia longiscapa* or *Cristaria molinae*, which are also endemic in Latin American deserts, or liliaceous plants that grow in the Sahara, such as *Asphodelus refractus*.
Some flowers, such as the hemerocallis or 'day lily', are not simple flowers: their flowers grow in groups on the plant; but as each stem terminates in a unique and impressive specimen it is still easy to find and study the various flower parts.

5. *Calandrinia longiscapa* plants in their natural environment, *Huasco* region, Chile

6. *Calandrinia longiscapa* flower, Chile

5 6

7 et **8.** *Cristaria Molinae*, Chile

9. *Nolana paradoxa*, Chile

► The whole class observes the brilliant colours: the red or bright yellow of the poppy, the deep violet of *Calandrinia*, the subtle mauve of *Cristaria*, the clear blue of *Nolana*, or the golden yellow, vibrant red or pure white of desert cacti or iridaceous plants.
► The teacher explains one of the main reasons why the petals are so colourful: the highly coloured flowers are a strategy to attract insect pollinators, which are not very common in the drylands. The teacher also points out that all flowers play the same key role in the ecosystem: by producing seeds, they enable the species to reproduce.

► Using samples they have brought back to the school, the pupils carefully examine each plant noting the uniform colour of its petals and the relative simplicity of its outline (the shape and size of petals, stems and leaves). They begin to arrange the flowers according to their colour, and consider how best to render the colour of each flower using water-based paints.
Split into two groups, they try out two alternative methods:
• They use the uniformity of the paint to capture the outline and the precise colour of the flowers, making coloured sketches from observation.
• They carefully mix the paints to match the colour to the specimen as closely as possible; then they dip the specimen into the paint and use it to make an imprint of the plant directly on paper.

4. Acquire the concept of inflorescence and broaden the colour exercise to the study of all flowers

► After studying the plants with simple flowers that grow singly on a peduncle (and excluding the *Compositae*, which are not in fact simple flowers), the pupils now turn to flowers that grow in groups, known as '**inflorescences**'. An inflorescence is an arrangement of flowers grouped together on a single stem.

► The teacher shows the pupils how to distinguish several types of these:
• A **spike** is an inflorescence in which the flowers are joined directly to a single stem, without a peduncle.
Example:
The fragrant golden yellow spike of the mesquite (*Prosopis pubescens*), very common in Mexico.
• A **cluster** is an inflorescence in which each flower is attached to the stem by a peduncle.
Example:
The red clusters of the bladder dock (*Rumex vesicarius*) in the Sahara.
• A **capitulum** is an inflorescence which looks like a single flower but is actually a set of 'florets' together on a base.
Example:
All daisies (*Asteraceae or Compositae*) found in South America or in the Arab countries.

Example of inflorescences in spike form

10. Australian mimosa, Blue Mountains, Australia

Example of inflorescences in cluster form

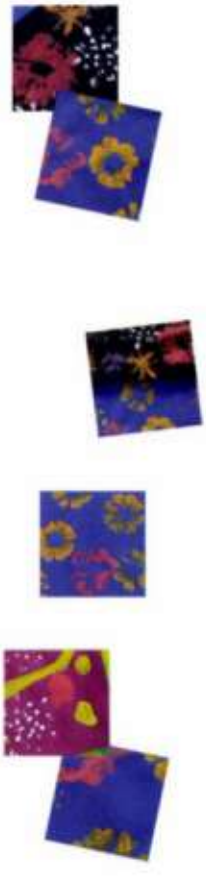
11. Indian sorrel or bladder dock *(Rumex vesicarius)*, *Biskra* region, Algeria

Example of inflorescences in capitulum form

12. *Anvillea radiata* (*Asteraceae*), Southern Morocco

► The teacher explains:
Although it looks like a centre surrounded by a ring of petals, the capitulum of a daisy such as the marigold (*Calendula aegyptiaca*) is not in fact a single flower. The centre is made up of hundreds of **tubular** flowers ('disc florets'), and each of the outer 'petals' is a **ligule** (or 'ray floret').
Other *Compositae* have completely tubular capitula (disc florets only), e.g. chamomile (*Matricaria pubescens*) or Chilean centaury (*Centaurea chilensis*).

► Once the pupils have grasped the concept of 'inflorescence', including umbel inflorescences such as dill (*Anethum graveolens*) and **cyme** inflorescences such as the oleander (*Nerium oleander*), they classify the inflorescences of the specimens they have collected by colour and add new colours to their original palette: the orange of the marigold, the pink of the oleander, the creamy white of the myrtle (*Myrtus communis*).
► Again split into groups and supplied with paint, the pupils depict these inflorescences according to their colour.
• In the paintbrush method they use long strokes for spikes and shorter ones for clusters.
For the clusters of the *Leguminosae*, for instance, a very common family in dryland regions, they learn how to paint the 'papilionaceous' crown of the inflorescence: the upright position of the banner (the upper petal of each flower), the keel projecting forwards (lower petals) and the two side petals like the open wings of a butterfly.
A few well-placed strokes of colour, and the flowers viewed from the front and in profile make up the cluster.
• For the direct printing method, the inflorescences (spikes, clusters, or capitula) are coated in paint and pressed onto the paper to leave some interesting relief effects.
► After experimenting a few times on paper, the pupils then produce boards of colour-classified plant paintings and prints.
This board format provides for a closer study of colour: simple and compound flowers (inflorescences) are represented side by side on the same board and different shades of the same colour can be distinguished.
Example:
On their 'orange' board, a Mexican class could show a gradation of tone from the spike of the ocotillo (*Fouquiera splendens*) to the flowers of the 'prickly pear' cactus *Opuntia ficus-indica* and the California poppy (*Eschscholzia californica*).



Plant prints made by children during a painting workshop (cf. p. 207)

► If the pupils wish, they can also paint the stems and leaves.
In the end, they are able to identify the flower and thus the plant from its colour.
► The teacher concludes the activity by reminding the pupils of the important role played by angiosperms in arid ecosystems.

5. Realize the importance of flowering plants in maintaining plant cover

The teacher begins by explaining the place of **pollination** and **fertilization** within the whole reproductive cycle of the species.

The role of flowering plants is twofold: production of seeds and sexual reproduction. A pollen grain and an ovule of the same species are needed to produce a seed: only a goatweed pollen grain, for example, will fertilize a goatweed ovule. So pollen grains need to get from stamen to pistil: that is pollination.

► The teacher asks the class questions about pollinators, and goes on to explain that:

• Some flowers are self-pollinating: the pollen falls directly from the stamens onto the pistil (hermaphrodite flowers).

• More commonly the pollen needed comes from another flower.

The pupils will have already seen how most flowers use colour, shape or scent to attract pollinating animals. Coloured petals advertise the presence of food; often, also, the flowers are big enough to provide a ready platform for the pollinator to land on.

In some cases there will even be line patterns or other marks to guide the visitor towards the pollen.

• Insects are the most important pollinators, particularly bees: most fruit and vegetable crops depend on them.

• Birds and some mammals are also pollinators.

Some of the animals that live on the *saguaro* (*Carnegia gigantea*) play a key role in the pollination of its magnificent red or white flowers. They include the hummingbirds *Archilochus alexandri* and *Archilochus colubris*.

13. Example of *Fabaceae*, *Atacama* desert, Chile
©UNESCO/Olivier Brestin

14. Sturt desert pea (*Fabaceae*), Northern Territories, Australia
©Olivier Brestin

15. *Lupinus tassilicus* (*Fabaceae*), *Tassili N'Ajjer*, Algeria
©Michel Le Berre

16. Astragalus (*Fabaceae*), *Cappadocia* region, Turkey
©Michel Le Berre

13 14 15 16

17. Hummingbird pollinating a *saguaro*, Mexico

Similarly, the flowers of the baobab (*Adansonia digitata*) are pollinated by the **nectarivorous** (nectar-feeding) bat, *Eidolon helvum*.
Plants pollinated by these species have hard, flat surfaces for the animals to land on.
• Lastly, the wind is a pollinating agent for some flowering plants: grasses (wheat), or the ilex in northern Africa.
These wind-pollinated plants do not have flowers that attract insects; their flowers are more subdued, less showy.

► The teacher goes on to explain:
For a seed to be produced, pollination must be followed by fertilization of the ovules.
The teacher explains that in flowering plants the ovules are enclosed in the ovary.
When a grain of pollen falls on a receptive stigma a pollen tube is formed all the way down into the ovary to an ovule. The ovule is fertilized and becomes a seed.
Next, for the species to reproduce successfully the seeds have to be dispersed.

► The teacher concludes by explaining that the production of seeds from flowers is essential to the formation and maintenance of plant cover in dryland areas.
• Wild plants – plants which grow spontaneously in nature, without human intervention – are dependent on reproduction by seeds for their survival. These plants are precious in dry ecosystems where plant cover is sparse and easily damaged, since they actively help to conserve and develop the ecosystem's plant life, thus maintaining its equilibrium.
• A plant species survives by producing flowers and seeds:
If it germinates, flowers, produces seeds and dies within a single year, it is known as an **annual species.**
If it flowers and produces seeds year after year, it is known as a **perennial species.**
Flowers – or the seeds they produce – are also a means of surviving years of drought: the plant seeds remain buried in the ground ready to germinate the following year or when the rains return.
Example:
Ephemeral plants such as *Levenhookia sp.* in the Australian desert.

Not only do flowering plants help maintain plant cover, they also increase the plants' life expectancy and persistence.

02 Form and Design: The Anatomy of Plants

Level ★ easy

Place classroom and outdoors

Duration 2 sessions

Objectives

1. Discovery of the environment

The pupils learn about plant anatomy and habit by looking carefully at plants (especially trees), first from a distance and then up close. Observation alternates with drawing.

2. Knowledge and comprehension

By identifying plants from a distance and studying their shape and growth, the pupils learn how external factors affect the habit of trees and shrubs; they realize the vital part played in dry ecosystems by plant cover, particularly broad-leaved trees.

Methodology

1. Note the structure and habit of plants through observation at a distance

► The teacher gets the class to look carefully at individual plants in their entirety.
The teacher advises the pupils to focus their attention on the trees and shrubs in the local environment.
► The class considers:
• What is the tree's overall structure?
• What is its architecture?
• Are the trunk and branches visible?
• Do they act as a framework, as pillars and lintels do in a building?

Concentrating mainly on broad-leaved trees, the pupils observe how each tree has a particular **habit**, taking up a characteristic shape which depends on the number and size of the branches and the angle they form with the trunk.
A network of smaller branches is attached to this basic structure, ending with the smallest twigs. The crown of leaves is distributed over the whole structure when the tree is in leaf.
The pupils describe a tree's habit, based on its trunk and main branches, and draw sketches.
Does each species have its own characteristic habit?
For this exercise, which is designed to teach the pupils how to identify trees from a distance, the teacher makes use of the practical knowledge of local inhabitants and the elders of the community. The pupils investigate:
• Local people can identify particular plants from a distance – trees or shrubs worth a long walk to pick fruit or find fodder for their animals. How do they tell what kind of tree it is?
• In Arab and African countries people can distinguish among the different species of acacia: *Acacia tortilis*, *Acacia raddiana*, *Acacia nilotica*, *Acacia senegal*? (cf. sketckes p.72-73). How do they identify thorny trees and shrubs? How to tell an acacia from an argan (*Argania spinosa*)?

18. *Acacia tortilis, Tassili N'Ajjer*, Algeria

• How to tell the difference between a tamarind (*Tamarindus indica*) and a shea (*Vitellaria paradoxa*) in the Sahel?
• How to tell the various shrubs apart in South America: the creosote bushes (*Larrea divaricata*, *Larrea tridentata*), and the different varieties of Prosopis (*Prosopis chilensis*, *Prosopis pubescens*)?

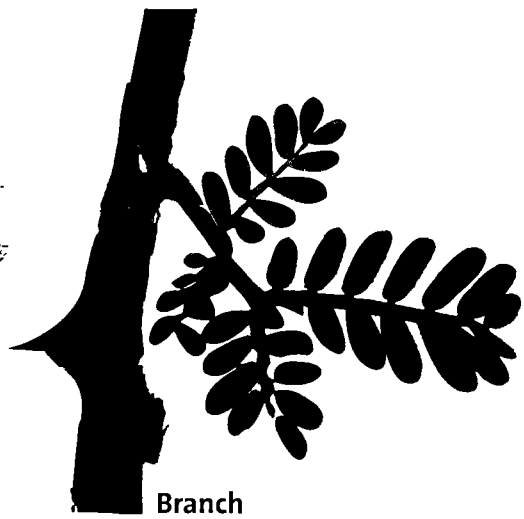
► The pupils draw sketch after sketch. They bring life to their drawings, the outline of which is not projected intellectually but is the outcome of an inner play of forces.
They capture the tree's energy, its height and strength – the baobab, for instance (*Adansonia digitata*), a characteristic tree of the Sahel, which grows both upward and outward.

2. Add some basic ideas about plant growth

► The teacher stresses the importance of the long woody roots by which trees and shrubs fix their trunks to the ground.
• Most trees have two transport networks: one for water, known as the **xylem**, and the other for food, the **phloem**.
• The roots draw or 'suck up' water and mineral salts from the soil.
• This upward suction through the trunk is driven by evaporation from the leaves, and results in a column of water rising from the bottom of the tree towards the top, just like a pump.
The overall shape of a tree is largely determined by its 'system of pipes', just as the shape of a leaf depends on its network of veins.
The Swiss painter Paul Klee made a special study of this in his 1926 educational sketches: "The two-dimensional shape that emerges depends on the hierarchy of lines. And where the line runs out of power, there the outline appears; this is the flat shape's boundary".

Acacia tortilis

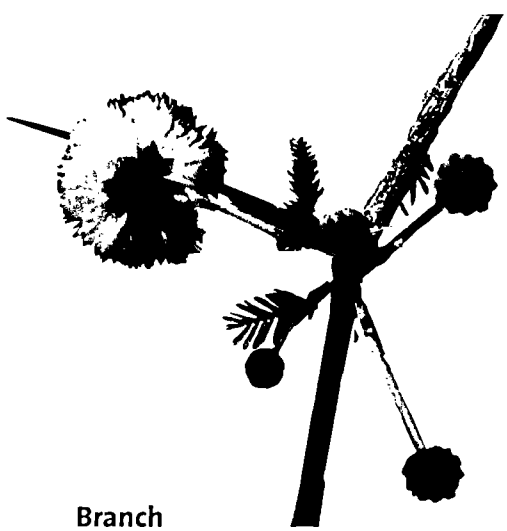
Tree



Branch

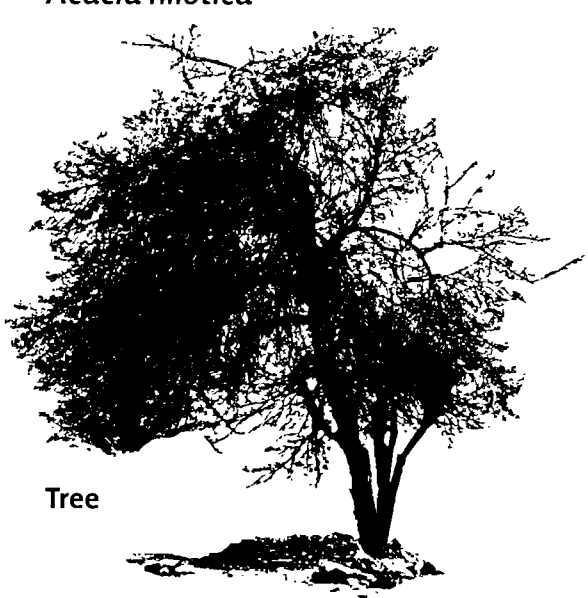
Acacia seyal

Tree

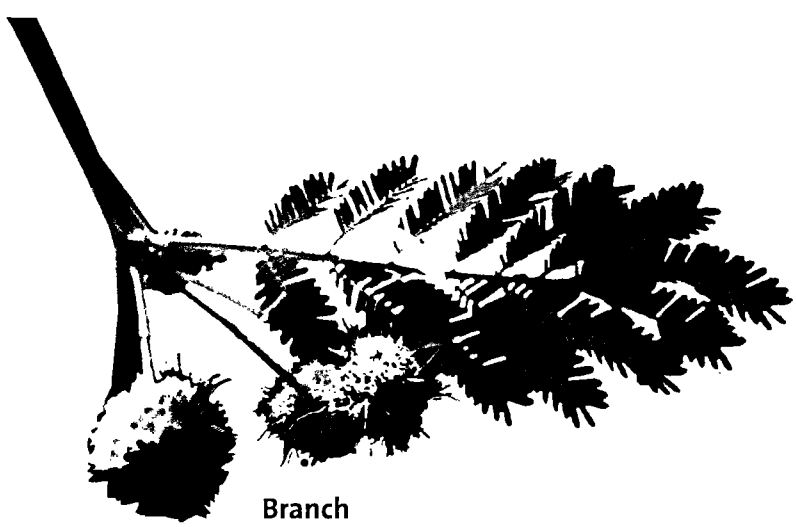


Branch

Acacia nilotica

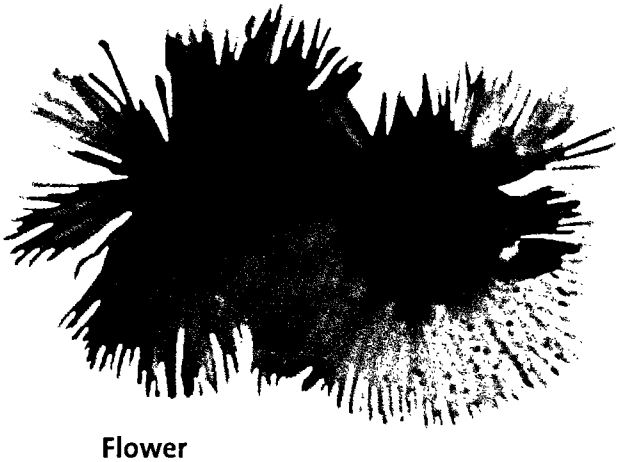


Tree

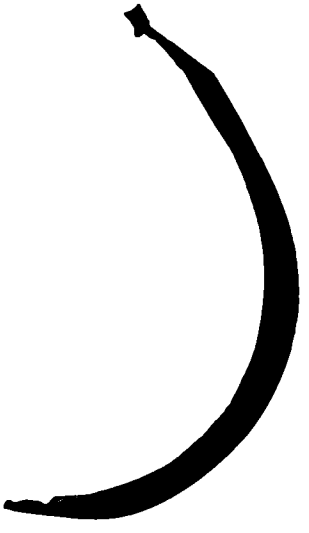


Branch

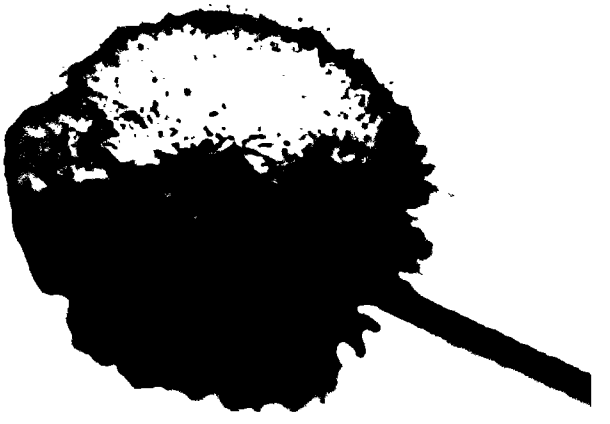
Pod



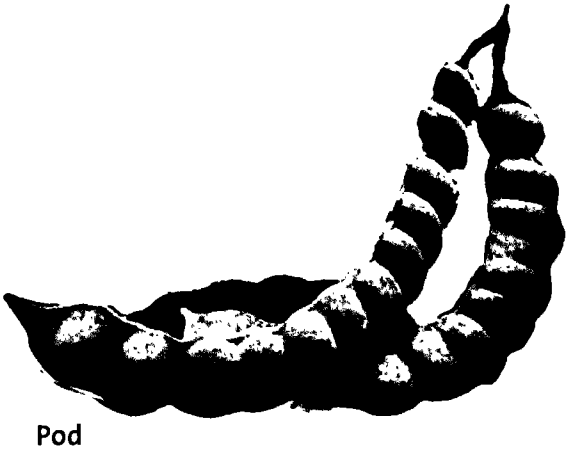
Flower



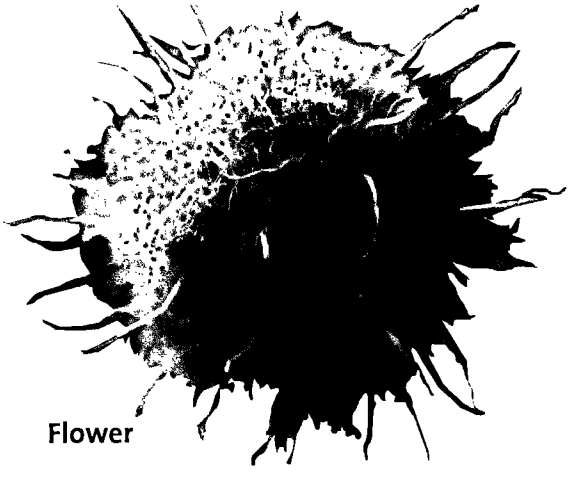
Pod



Flower



Pod



Flower

3. Realize how geometry works in nature through close observation

► After studying the shape of whole trees, the pupils turn to the leaves and consider the relationship between the overall shape and the hierarchy of lines.

► Focusing on the morphology of a leaf, the pupils observe and sketch the shape of its **lamina** and **petiole**.

► They also observe the veins that divide the leaf into visible cells, each with its own sap supply. A leaf studied through a binocular hand lens, if the school has one, is a fascinating sight!

► The pupils learn and sketch the difference between the two main types of leaf:

- **Simple** leaves, like those of the holly oak, fig (*Ficus platyphylla*) or olive (*Olea europaea*);
- **Compound** leaves of the acacia (*Acacia raddiana*, *Acacia nilotica*), which are composed of several **leaflets**.

► They then learn to distinguish different arrangements of the leaves on the stem, and note the orderly and precise pattern of each species.

They distinguish, for instance:

- *Alternate* leaves, arranged on either side of the stem one at a time along the stem's length, as in the holm oak or fig. There are *alternate* leaflets too, as on the date palm (*Phoenix dactylifera*) ;
- *Opposite* leaves: two leaves on opposite sides at each node, as in the myrtle (*Myrtus communis*);
- *Whorled* leaf arrangements: three or more leaves at each node, as in the oleander (*Nerium oleander*).

19. Simple opposing leaves of an olive branch (*Olea europaea*).

20. Composite leaves of acacia (*Acacia raddiana*) from several leaflets.

21. Alternate simple leaves of a fig branch (*Ficus platyphylla*).

22. Row of baobabs (*Adansonia digitata*), *Goree Island*, Senegal

► The pupils' sketches and drawings enable them to see that all the small branches of a given tree share the same arrangement of leaves on the stem and the same spacing of the leaves (**phyllotaxy**).
They note that the phyllotaxy also determines the distribution of twigs on the branch and the distribution of branches on the trunk.
Example:
The date palm (*Phoenix dactylifera*) is not a tree but an arborescent **monocotyledon**. The arrangement of the alternate leaflets that make up its leaves is repeated in the arrangement of the leaves themselves, which grow laterally in spirals around the stipe.

► The teacher then suggests a period of observation in which the pupils can appreciate the organization and geometry of plant growth.
► Finally, the teacher gets the class to consider the various factors that can disrupt the natural growth of a tree or bush:
• What makes a particular tree look irregular?
• Have some parts been unable to develop properly because of the lack of water or light they need?
• Have other parts been bent out of shape because of the sun, shade or wind?

4. Think about the way external factors affect the plant's habit

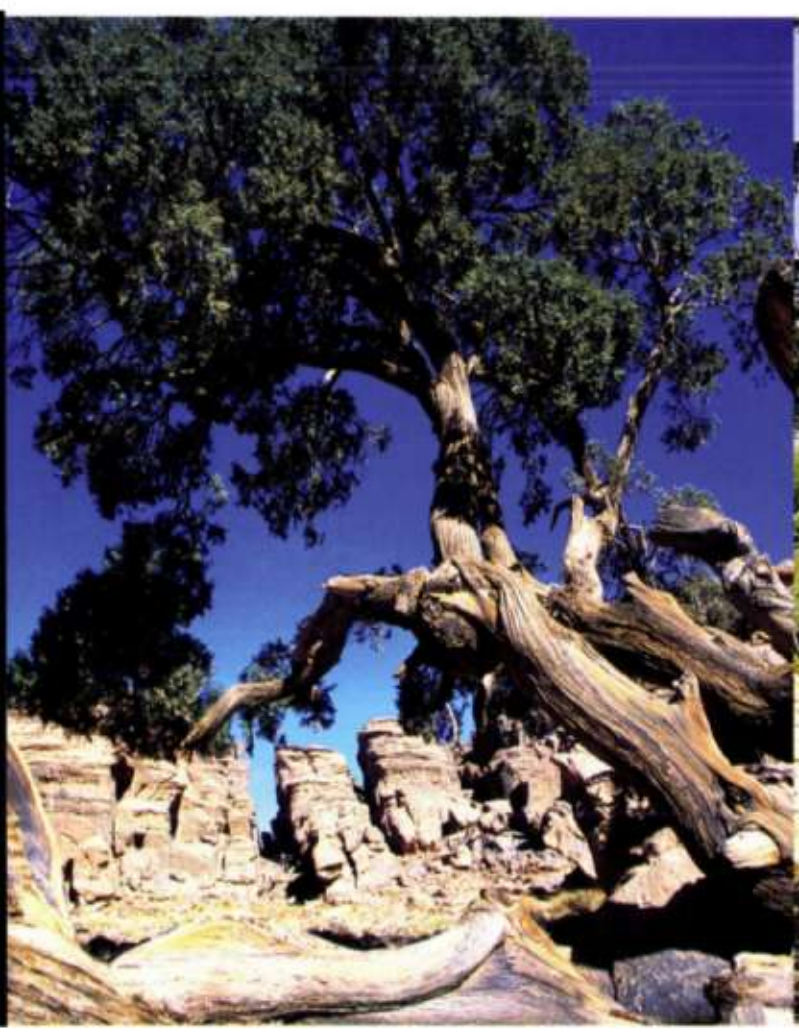
► The teacher recalls that a plant's shape is pre-programmed by its **genetic make-up.**
However, various factors can 'disrupt' this programme.
The class is encouraged to look at three factors:

A. The effect of the wind

A tree may grow out of shape because of the raging winds, especially in dryland regions. For example, many Aleppo pines are flag-shaped because of the wind.
The wind may burst the buds on the exposed side of the tree, so that most of the growth takes place on the opposite side.

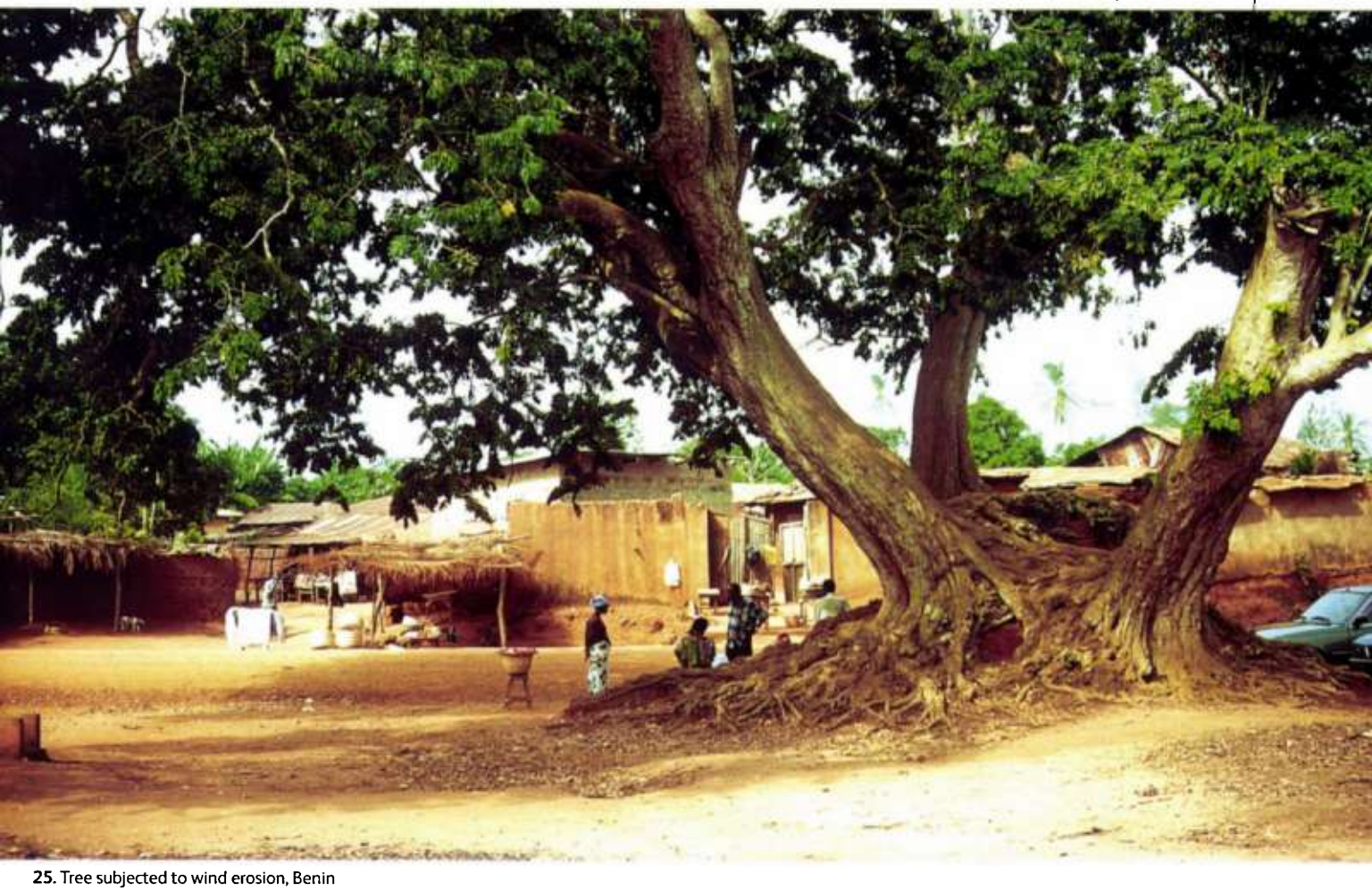
B. The impact of human beings

- Sometimes humans randomly collect from plants they come across: foliage to feed their cattle, branches as firewood for cooking. People's tracks can be followed merely from the state of trees where they have passed;
- Sometimes they remove foliage evenly and carefully; this can actually stimulate vigorous plant growth;
- Sometimes they take too much foliage too often, causing the plants to wither and die.



23. Cypress deformed by wind erosion, *Tamrit, Tassili N'Ajjer*, Algeria
©Olivier Brestin

24. Argan tree under pressure from herbivorous animal species, Morocco
©UNESCO-MAB



25. Tree subjected to wind erosion, Benin

C. The impact of herbivores

The teacher recalls that in very dry regions vegetation is so scarce that herbivores are forced to feed directly on **ligneous plants.**

- In the dry season, animals tackle persistent (**evergreen**) foliage, eagerly devouring the small amount of plant matter they provide;
- When the tree has lost its leaves, they turn to thorns and twigs; they will graze the young shoots as the plant starts to build up its foliage again. This is known as **overgrazing** and damages the plant.

The teacher continues: when the activities of human beings and herbivores together put the tree under too much pressure, its very survival is at stake. But all ligneous plants have an important function in dryland regions; when they destroy trees, people contribute to the degradation of the terrain: all the tree's functions are lost, including the many benefits it offers, especially when it has a proper crown of foliage.

- The tree provides shade for people and animals to shelter from the sun. Village elders will meet under a 'palaver tree' to consult and make decisions.
- Its crown acts as a windbreak and protects crops. It fulfils this role even better if it is suitably pruned.
- Its fallen leaves decompose and enrich the soil with organic matter.

(For more detail about the ecological functions of plants, including trees, see Chapt. 2, act. 4, p. 85).

03 Dryland Living: How Plants Adapt to Deserts

Level ★★ intermediate

Place classroom and outdoors

Duration 3 sessions

Objectives

1. Discovery of the environment

The pupils learn about xerophytes – plants adapted to dry conditions – by associating these plants with common everyday objects making sets of drawings and comparing the two.

2. Knowledge and comprehension

The pupils identify and assimilate the main anatomical, morphological, physiological and climate-related characteristics and adaptations of plants that live in dry ecosystems.

Methodology

1. Notice xerophilous (dry-loving) plants

► The teacher gets the pupils to concentrate on certain bulky-shaped typical dryland plants notable for their thick stems or leaves, (cacti, cactus-shaped euphorbia, agaves), their rounded trunks or branches (*Aloe dichotoma*, *Pachypodium lamerei*), or their bulbous stems and oversized trunks (baobabs).

► The teacher explains that over time these plants have adapted to dry conditions by building up water reserves in special organs – hence their bulky shapes.

2. Associate plants with objects by drawing

► The pupils continue to study **xerophytes** by looking for possible associations between the look of a plant's anatomy and some everyday object.

► In each case, they produce drawings comparing the plant with the object it calls to mind.

Example:

Baobab (*Adansonia digitata*) / a bottle;

The baobab (there are many species) is often nicknamed the 'bottle tree'. Its crown is small compared with its enormous trunk; its roots are very deep so that it can draw up groundwater, which it stores in its trunk like a bottle storing its contents.

Other possible examples:

Saguaro (*Carnegia gigantea*) / a candle, or a cigar;

Pachypodium (*Pachypodium namaquanum*) / a club;

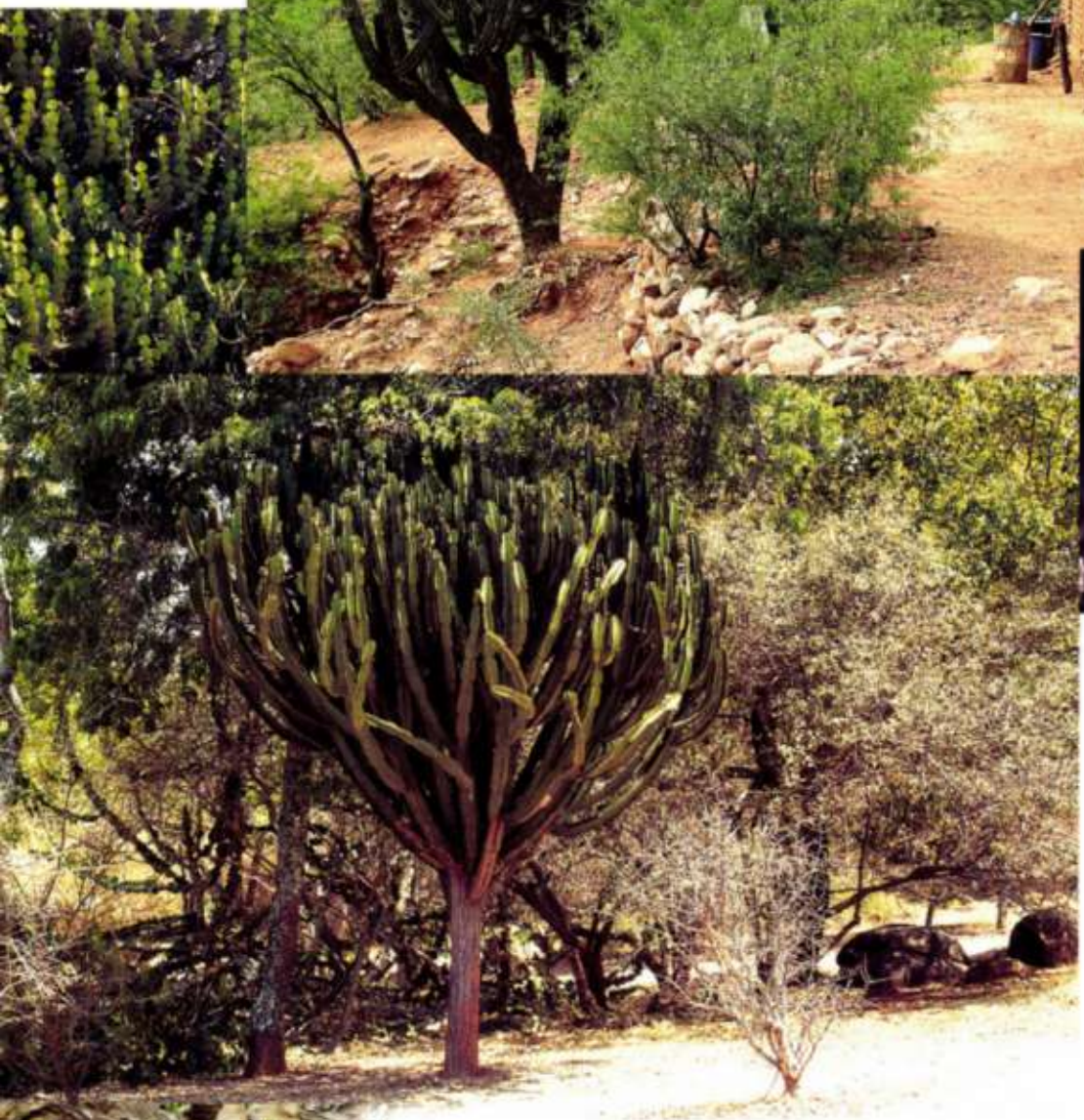
Candelabra cactus (*Browningia candelabris*) / a candelabra;

Prickly Pear stem segments (*Opuntia ficus-indica*) / a tennis racket;

Hemispherical cacti such as *Echinocactus grusonii* / a cushion;

Desert Barrel cactus *Ferocactus cylindraceus* / a barrel;

Maguey leaf (*Agave americana*) / a cutlass blade.



26. Giant cacti in front of a house, *Batopilas* region, Mexico
©UNESCO, Olivier Brestin

27 and **28.** Cactiform euphorbia, Zimbabwe (detail)
©Michel Le Berre

29. Arborescent euphorbia, Zimbabwe
©Michel Le Berre

30. Isolated cactus, *Batopilas* region, Mexico
©UNESCO, Olivier Brestin

31. Group of cacti, *Tenerife*, Canary Islands, Spain
©Michel Le Berre

The exercise highlights the thickness and capacity of the plants' special organs.

► This allows the teacher to explain the concept of succulence, or water accumulation, and the way water is stored in reserve organs such as leaves, stems, trunks or even roots and tubers, depending on the plant.
Succulence is just one of the physiological adaptations developed by plants to cope with the shortage of water in dryland ecosystems; there are others.

3. Place xerophytes in the context of plant cover

Plants are amazingly good at combating water loss and transpiration.
The teacher explains the advantages of some of their adaptations.

► First, the teacher reminds the pupils of some of the general characteristics of plants and their essential role in dryland regions:
• Without plants, there would be virtually no life on Earth;
• All the oxygen we breathe has been released into the air by plants;
• Like us, plants respire and transpire;
• **Transpiration** cools the air by several degrees. It is really important therefore to preserve plant cover in dryland ecosystems because plants help to regulate the dryness and heat of the local atmosphere around them (microclimates).
• Most plants are rooted in the soil and capture solar energy to make their own food by absorbing water through their roots and carbon dioxide from the air.
• In their leaves and stems, plants make simple sugars from water and carbon dioxide using the light energy emitted by the sun (photons) with the aid of a green pigment called **chlorophyll**. This chemical reaction is called **photosynthesis**.
During photosynthesis, plants also give off oxygen as a by-product.
• As they incorporate the sugars made for their own consumption, plants produce their vegetable matter, which is then eaten by other living organisms (herbivores).
• Even where plant cover is sparse, as in dry ecosystems, life generally depends on it as plant cover is at the base of the food chain. (For a detailed look at the ecological functions performed by trees and other plants, and the 'ecosystem' that a tree itself constitutes, see Chapt. 2, act. 4, p. 85).

► Once the concepts of photosynthesis and transpiration have been introduced, the teacher explains how xerophytes have adapted to reduce water loss through transpiration, and to avoid drying out.
Transpiration is activated by dry air: water is drawn in from the soil by the roots and pumped up through the trunk to the leaves where it evaporates through the transpiration pores or **stomata**. The stomata also allow the carbon dioxide to enter the plant; this is needed for chlorophyll to do its work.
In order to limit water loss through transpiration, and to reduce the rate of photosynthesis (which also requires a considerable amount of water), plants have adapted in various ways.

4. Learn about xerophytes' main anatomical and physiological adaptations

► The teacher explains the following points:
• Reduced leaf area: the leaves of desert plants are often small, thick and tough-skinned resulting in a smaller surface area for evaporation.
Examples:
The leaves of the argan (*Argania spinosa*) or the jojoba (*Simmondsia chinensis*).
Some plants may even have no leaves at all.

32. Giant *cardones* cacti and pampa grass (*Cortaderia selloana*), *San Pedro de Atacama* region, Chile
©UNESCO/Olivier Brestin

• The stems can take over from the leaves to produce food by photosynthesis.
This is the case with all cacti.
• Sunken stomata help to reduce transpiration.
• Leaf surfaces are thick and hard; the pupils will already have noticed the tough cuticle of the leaves; they can observe the waxy coating of cactus stems, which also helps to limit transpiration.
• Another remarkable feature of xerophyte anatomy is that in many cases their leaves have become spines – again, in order to reduce water loss. Cactus spines are in fact modified leaves, which have shrunk to needles in a compromise between the need to limit the leaf's evaporation and the need for some surface area for photosynthesis.
Cacti from the Americas are not the only plants whose leaves have become spines. In Africa, euphorbias have developed similar strategies for coping with their dry environment. This is known as 'convergent evolution' of different species (cf. Chapt. 1, act. 5, p. 41).
► The teacher explains:
Generally speaking, the vegetation of dryland ecosystems is dominated by prickly plants. Many ligneous plants have spines as well as small leaves in order to combat the dry environment and to discourage herbivores (although that does not prevent such animals from browsing on them).
Examples:
The teacher could mention the sharp spikes of the desert date (*Balanites aegyptiaca*), which can be up to 7cm long, the strong spines of the argan (*Argania spinosa*), many acacias (*Acacia nilotica*, *Acacia raddiana*), and the balsam or myrrh gum tree (*Commiphora myrrha*).

5. Reintroduce drawing and the association of objects with prickly plants

► From the examples mentioned, depending on the region, the teacher emphasizes the diversity of spines: short and strong, thin and stiff like thorns (*saguaro*), curved, hooked, barbed or downy.
► The teacher gets the class to make a new set of drawings, this time of prickly plants.
The pupils begin their sketches by directly observing the spines in real life.
► They draw close-up sketches of parts of the plant and prickly fruits, focusing on the detail of the spines, which are different in each case.
The variety of spines is matched by the diversity of 'spiky' plant shapes.
► The pupils review the many popular nicknames given to prickly plants in their own culture: 'pin cushion', 'hedgehog', 'porcupine' or 'fish hook'.

33. Detail of a giant *cardon* cactus, Chile

34. Detail of a cactus, *Batopilas* region, Mexico

35. Detail of cactiform euphorbia (*Euphorbia echinus*), Morocco

Here again the association with objects or animals is obvious.
► Once more the pupils set about making sets of drawings and comparing them; the funnier and more evocative the better.
► To complement their drawings the pupils look for common expressions or sayings (from their country, region or community) that mention prickly trees, shrubs or (in America) cacti, and refer directly to their physical appearance or the associations and metaphors that arise from it.

6. Recognize other morphological, physiological and climate-related adaptations of xerophytes

► The teacher highlights the particular morphological development of roots, which are primarily designed to gather water.
Plants maximize water absorption either by spreading their roots out horizontally just below the surface like bushy plants (for instance *Zilla spinosa* in the Arabian Peninsula whose roots are sometimes partly exposed), or by developing taproots which grow vertically down into the ground to reach the water table, like wadi acacias (*Acacia raddiana*) that can reach as far as 35m underground to find water.

► The teacher points out another set of physiological adaptations; the way the whole individual plant controls its own internal flows of water and nutrients.
When there is not enough water available, the stomata close to block transpiration.
The stomata also close if the plant is over-stressed by heat or sunshine, and the rate of photosynthesis may fall in the middle of the day, slowing down the plant's growth.
Example:
One example is the myrtle (*Myrtus communis*), found all around the Mediterranean basin, and beyond it as far as Mauritania.

► Lastly the teacher mentions other, climate-related ways in which xerophytes have adapted to make sure that their period of vegetative activity coincides with favourable climatic conditions.
► The teacher gives various examples:
• Some trees or shrubs avoid excessive water loss by shedding their leaves at the start of the dry season: for instance, the arborescent aloe of the coastal plains of the Namib desert or *Acacia mellifera*, a species of acacia.

36. Desert sparrow (*Passer simplex*) on *Balanites aegyptiaca*, Niger

37. Flowering *Maerua crassifolia*, *Tassili N'Ajjer*, Algeria

38. *Prosopis tamarugo* thorns, *Atacama* desert, Chile

• Other plants, such as the Mediterranean broom *Calycotome villosus*, grow leaves in winter and spines in summer. Others alternate between leaves and spines depending on the weather conditions, such as some prickly plants of the Sahel including the tropical jujube or Sahel apple (*Ziziphus mauritania*).
• Acacia albida (*Faidherbia albida*) is a highly prized tree because of its inverted cycle: it keeps its leaves during the dry season and sheds them later when the rains come thus providing fodder and highly nutritious material during the dry season.

► The teacher draws the pupils' attention to the way some species slow down their life processes or become dormant to escape dry conditions:
• **Geophytes** such as tulips or wild onions (from the Greek 'gê' meaning 'earth') can survive for years without rain in underground form, living on water in their storage organs (bulbs, tubers or rhizomes).
• Others survive between downpours as seeds: ephemeral plants (or pluvio-therophytes) which germinate very quickly following the rain, and develop their first inflorescences within a few days, transforming a barren area of desert into a flowered prairie. One example is the small yellow flower of *Koelpinia linearis* in Algeria.

7. Produce a final set of comparative drawings that includes the idea of a cycle

► To illustrate the great variety of ways in which plants adapt to dry conditions, the teacher asks the pupils to make a new set of drawings illustrating the adaptations of xerophytes throughout their cycle: the cycle of annual or seasonal changes, or the plants' own reproductive cycle.
► The pupils produce these drawings over a number of sessions when the weather is changeable or at the end of the rainy or dry season.
► These are 'before and after' drawings.
The drawings illustrate the plants' adaptations to dry conditions and their water conservation strategies; they show how the plants manage to grow despite the constraints.

Examples:

N°1:
Tree after rain / Tree during a dry spell,
Tree with foliage / Tree without foliage,
Coloured-in areas of foliage / Simple line drawings.

N°2:
Shrub during the rainy season / Shrub during the dry season,
Shrub covered in leaves / Shrub covered in spines,
Layers and colour / Line drawing of spiky appearance.

N°3:
Cactus after rainfall / Cactus during a dry spell,
Swollen cactus, saturated with water / Dry cactus,
sagging on one side (barrel cactus),
Swollen stem, folds disappearing / Accordion-pleated stem (*saguaro*).

N°4:
Comparatively bare stem of a young cactus / Prickly stem of a mature plant,
Smooth surface, coloured in / surface covered with detail, line drawing.

N°5:
Ephemerophytes in dry conditions / Ephemerophytes after rain,
No plant cover / Plant cover,
Mineral landscape / Vegetation,
Dull colouring / Bright colours.

Cactus stem before and after the rain

40

41

39. Cactus, *Batopilas* region, Mexico

40. Flower of *Miqueliopuntia miquelii*, *Huasco* region, Chile

41. Cactus column, *Pan de Azucar* National Park, Chile

04 The Tree as Ecosystem

Level
intermediate ★ ★

Place
classroom and outdoors

Duration
5 sessions

Objectives

1. Discovery of the environment

By creating a vertical, almost life-size mural of a tree, the pupils discover all the tree's ecological functions within the ecosystem and identify the animal and plant organisms that use it as their habitat (for shelter and food).

2. Knowledge and comprehension

By studying the tree in detail, the pupils recognize the synergy between living organisms and their environment (or habitat). They understand the importance of ligneous plants better: in dryland ecosystems a tree makes up a veritable ecosystem in itself.

Methodology

1. Draw the general shape of a tree

► The intention is for the pupils to create a monumental mural taking up a whole wall and portraying a tree from roots to crown. After an initial observation exercise the detailed mural is produced in stages, in layers of habitats one above the other from the bottom to the very top; it illustrates the active ecological role played by each part of the plant, together with the organisms that live in it and use it for their own needs at various stages of the plant's reproductive cycle.

► The pupils begin by drawing the outline of a tree, taking care to produce a general and simple outline.

In this activity the tree should remain anonymous unlike in *The Plant as Mascot* (cf. Chapt. 2, p. 106), where the aim is to choose a particular plant species and make it a totem or mascot, as a celebration of all it does for people in their everyday life.

Here a non-specific tree mural allows the pupils to appreciate how tree species are essential to the ecosystem, play an important ecological role, occupy a key position in the food web and provide vital shelter for species and for sexual reproduction.

► The teacher advises the pupils to allocate 60cm at the bottom of the wall for the underground roots and soil. This underground part is drawn to a smaller scale, although the real distances involved are stated (the depths of the groundwater, topsoil, roots, and so on).

The general outline of the tree allows the class to link the component parts while keeping them in proportion.

2. Add the tree's roots and surrounding soil

► The teacher gets the pupils to look carefully at the roots of ligneous plants in the local environment.

They find and observe plants whose roots are exposed, such as uprooted plants and dead trees. They look out for shapes among the knots and twisted roots that evoke animals or familiar objects.

► They can look for roots that make likely subjects for further shaping, to bring out these half-seen images; they use tools to cut, hollow and carve their pieces of root, and finally sand their sculptures smooth.
They give free rein to their imagination, and make up stories based on these images seen in the roots: many cultures tell of djinns, gnomes and spirits living in dead trees.
► Continuing this idea, the pupils investigate local or regional meanings attached to roots, and ways of using them for domestic, medical, symbolic or sacred purposes.
Examples:
In tropical Africa the thick branches of the baobab (*Adansonia digitata*) are thought to look like roots, giving force to the idea that the tree draws its strength from the sky.
Around the Mediterranean basin, particularly in northern Africa, the forked root of the mandrake (which looks like a small doll) is still used as a talisman, and for making various potions.

Hence, there is some familiarity in the idea that trees draw their power from their roots buried underground, hidden in the dark.

► The teacher continues:
Without roots, terrestrial plants would adopt small and simple forms like mosses and fungi.
Rooted terrestrial plants such as trees could never survive without the roots that support them and help take in water from the soil.
► The pupils recognize that one of the physical and biological resources that plants and roots need in order to survive is the solidity of the ground, thus providing the firm hold that trees need if they are to stay upright and resist wind erosion and runoff.
► The teacher describes how trees and roots themselves perform a corresponding ecological function, especially in dryland ecosystems: roots keep the ground stable, and structure the soil with their ramifications. This helps rainfall to soak into the ground, slowing runoff and reducing erosion.
► Then the teacher talks about the water the tree needs to make its food, explaining how trees in arid regions maximize their water uptake by sinking their roots deep into the ground until they reach the water table.

► Using this information, and depending on their region, the pupils elaborate the intricate root system through its representation on the mural.
Examples:
In Saharan Africa, they could draw the **taproot** of a common acacia such as *Acacia tortilis* or *Acacia raddiana*, which goes more or less straight down to astonishing depths (up to 35 m). Smaller lateral roots are connected to the main root.
In the Sahel, they could draw the shea (*Vitellaria paradoxa*), a tree of medium height (10 to 15 m) with a very intricate root system, which is highly effective at countering erosion.
In arid parts of Latin America or South Asia they could draw the wide-spreading **fasciculated** root system of a Chilean mesquite or *algarrobo* (*Prosopis chilensis*), with its many deep roots up to 15m in length.
In every case the root systems are shown in truncated form in the lower part of the mural; they may be illustrated in greater detail using smaller 'windows'* at the side.
The water table is shown even lower down, framing the mural's bottom edge. Details of the real depths are given.

* As seen in p.50, windows are drawings that appear in the margins with or without annotations and portray a detail or a close-up of a particular element. They mostly appear in a circle with an arrow to the main picture.

42

43

44

45

42. Baobabs (*Adansonia digitata*) during the dry season, central Guinea
©Michel Le Berre

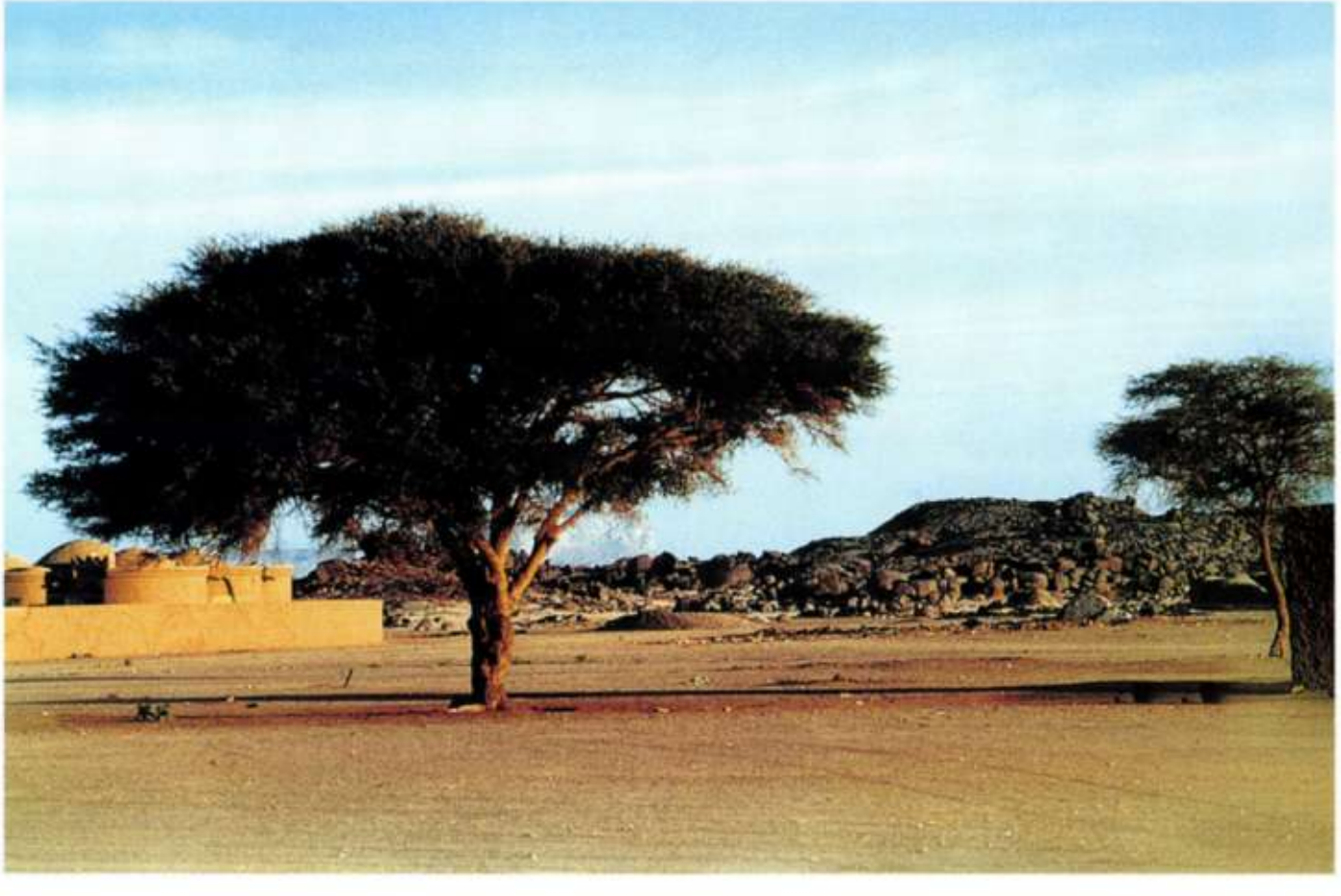
43. Buttresses of the kapok tree (*Ceiba pentandra*), *Baro*, Guinea
©Michel Le Berre

44. Exposed tree roots due to river erosion, banks of the *Mékrou*, Niger
©Michel Le Berre

45. *Ficus sp.* roots, W region, Niger
©Michel Le Berre

► The pupils represent the gradual infiltration of runoff from the trunk through to the lateral roots by using a series of straight arrows drawn in a downward direction.
On the ground, around the trunk, the class shows the surface to be more richly covered with plants benefiting from and fed by the greater soil humidity in such places. The pupils draw in plenty of fleshy plants and grasses.
In arid ecosystems, the active drawing up of undergroundwater contributes to the overall development of the ecosystem. Species that do this are particularly useful.
Example:
Acacia tortilis can bring up almost 250 litres of water in one night. This benefits all the vegetation in the ecosystem.
► The pupils can draw a representation of this phenomenon, known as an 'hydraulic lift'.
During the night, while the stomata are closed, trees continue to absorb undergroundwater; the water is no longer lost through evaporation and is redistributed in the soil by the **radicles** nearer the surface.
► The teacher explains the following.
At the end of the tree's lateral roots are the radicles, where the tree absorbs the mineral nutrients it needs to make its own cells: nitrogen, phosphorus, potassium, calcium, magnesium, and others.
The tiny absorbent hairs surrounding the radicles in the soil absorb water and mineral salts, which are then transported via the xylem to the main roots and up towards the tree trunk.
► The teacher explains the nutrient cycle, illustrating it with an example, before asking the class to include it in the mural.

46. *Acacia albida, Iférouane, Aïr*, Niger



47. Villagers assembling under the shade of the palaver tree, in this case, *Acacia raddiana*

The teacher gives an account of various animals' activities to round out the presentation and enliven the description.

Example:

Faidherbia albida (or *Acacia albida*) is a nitrogen-fixing leguminous tree.

It contributes to the nutrient cycle in more than one way:

1. Through decomposition of its **litter** (the tree's debris of vegetable matter);

Every year leaves, flowers, fruit, dead wood and bark fall to the ground under the tree, where they decompose. The numerous dryland detritivores – termites, ants, acarids or beetles – feed on this dead plant matter (dry or rain-sodden), rotting wood and fungi. Everything that is not eaten by the detritivores is broken down by micro-organisms and decomposers, including bacteria such as *Azotobacter*.

Once assimilated or broken down in this way, the nitrogenous compounds of this tree's litter mix into the soil and improves its fertility. *Faidherbia albida* sheds its leaves at the start of the rainy season (unlike most trees in arid regions), so this litter is quickly decomposed and the nutrients rapidly become part of the soil.

The tree's powerful root system then absorbs these mineral nutrients, or nourishment, which it recycles and transports to other parts of the plant above ground. The nutrient cycle is thus established!

Animal organisms such as **iules** and centipedes give the trees valuable help: the tunnels they make allow air to descend to the roots; they bury decomposing plant matter in their tunnels, and by disturbing the soil they get the mineral nutrients nearer to the roots.

2. By bringing mineral nutrients to the surface;

The root system of *Faidherbia albida* is not only powerful, it is also deep, and brings to the surface mineral elements that are sometimes buried deep underground. The roots fix nitrogen with the aid of fixing bacteria such as *Mycorrhiza* found in the root-nodes of most leguminous plants, and in doing so bring minerals up nearer the surface.

In some cases they also put these elements back into the soil, either through root excretions or when the roots themselves rot and decompose.

It is thanks to its roots that *Faidherbia albida* can recycle fertilizing elements and reintroduce them into the soil in both these ways.

► Stimulated by the example given and the account of the animals' contribution, the pupils complete the root section of the mural.
They draw a loose soil, sandy or clayey (light brown), enriched with decomposing plant or animal organic matter, and the humus (dark brown), to which they add a quantity of pebbles and stones. They portray the soil aerated by transporter organisms, with detritivores on the surface and their habitats, depending on the region: the nests of compass termites (*Amiternes meridionalis*) in Australia, or of silver ants (*Cataglyphis bombycina*) in North Africa.

► It may be easier for the pupils to draw the various animal and plant species on separate pieces of paper which they then cut out and stick at the side of the main picture of the roots. This helps the class to count the species and show them more clearly.
► To complete this part of the mural, the pupils include a herbivore which comes to graze under the tree and adds organic matter to the soil.
Example:
In Africa, a gazelle such as *Gazella dorcas*, a dromedary, a zebra, an antelope such as *Oryx dammah*, or the rare *Addax nasomaculatus*.

3. Add the trunk and branches to the mural

What kinds of species live at the next level up?
► The teacher gets the pupils to feel and compare the bark of different plants, to study the growth rings on felled tree trunks, and to examine the hollow trunks and branches of aged specimens (of African baobab *Adansonia digitata*, for instance).
► The teacher explains certain features of the tree's woody parts: roots, trunk, branches and twigs:
• A tree grows in girth because of the **cambium**, a thin layer of cells extending to all its woody parts. The cambium layer is beneath the bark, under the fibrous tissue that transports the enriched sap and is known as the **phloem**.
Just beneath the bark is the sap, which contains mineral elements brought up from the soil as well as nutrients from the leaves.
• So the thickness of the bark protects this circulation of nutrients and the thin layer of cambium cells located just underneath.
► The pupils carefully compare the textures and colours of different kinds of bark: the rough bark of the *Tamarix aphylla*, the white-veined red bark of the *Acacia senegal*'s branches. On the tree-trunks they often notice the traces of various wounds that mar the evenness of the bark.
► Guided by the teacher, the class examines the notches made when the desert date (*Balanites aegyptiaca*) is **pruned**, the marks left by objects introduced into the bark (to make climbing easier), the scars left by stripping bark (for example in the case of *Adansonia digitata*), the holes bored into baobab trees to extract water, the bulges and swellings where branches have been broken or damaged by the wind, as well as traces of fire.

► The teacher again points out trees' adaptations to arid ecosystems, and explains how in many species the bark can heal itself, or extend its protective role in special ways:
• When a tree is damaged, sap flows out through the opening; the cambium cells proliferate around the edges of the wound to fill the gap. *Adansonia digitata*, for example, can easily regenerate its bark.
• Other species have developed a bark that is highly resistant and can prevent parasites from attacking or protects the tree from fire.
Examples:
When the bark of certain types of Australian eucalyptus like *Eucalyptus sp.* is damaged by fire, it secretes a protective gum that enables the damaged tree to produce new foliage from buds that are discreetly hidden.

48. *Eucalyptus melanophloia*,
New South Wales, Australia

49. *Ficus macrophylla*,
New South Wales, Australia

► The teacher continues:
• Though bark is tough, many insects, birds and even parasitic plants manage to get through it and feed on nutrients drawn from the tree.
• These living organisms form the base of the trunk's food chain.
► The pupils observe these species one by one and draw them on stickers, which can then be positioned onto the tree on the mural.
Which species can be found whose habitat consists of the trunk and branches?
First, many insects have **xylophagous** larvae which tunnel inside the tree's wood to feed themselves.
Example:
The larvae of the Capricorn beetle and others of the long-horned beetle family (*Cerambycidae*).
► The pupils draw a close-up cross-section of the trunk, showing eggs laid along the tunnels.
► They then sketch more stickers with other xylophagous adult insects such as wood-boring weevils of the *Curculionidae* family, which damage saplings by using their long snout to chew the bark.

50. *Butyrospermum pterocarpus* in flower, W region, Niger

51. Gecko (*Ptyodactylus hasselquistii*), *Ihérir*, Tassili N'Ajjer, Algeria

► They continue with various tree-living insects that feed on tree sap, such as *Crematogaster oasium*, found in the Sahara on *Acacia tortilis* or *Acacia raddiana*, or bugs such as *Dysdercus fasciatus* found on *Adansonia digitata*.
► In this way the class puts together a coherent food chain of animals in a series of portraits: As well as the obligate sap-feeding or wood-feeding larvae and insects that colonize the trunk, their predators need to be included.
• Arboreal reptiles that eat larvae and insects include the red-headed rock agama (*Agama agama*) or the fan fingered gecko (*Ptyodactylus hasselquistii*).
• Other carnivorous insects such as ground beetles climb trees to hunt for prey and also enjoy feeding on invertebrates such as ants, larvae and caterpillars.

Example:
The *Tamanrassat*, the Tuareg name for a nocturnal beetle found in Algeria.
• Birds, particularly warblers which nest in acacias, such as the common whitethroat (*Sylvia communis*); these are passerines which are great insect-eaters, and help maintain the tree-trunk food chain during their migratory visits.

► The pupils include each species by drawing it on a sticker and writing its name underneath.
► They draw pictures of the different types of shelter directly on the mural: nests, holes bored into the wood, and the galls of moths like *Amblypalpis olivierella* attached to branches of *Tamarix aphylla*.

4. Add the crown and foliage

Finally, what lives in the top storey supported by the crown and its twigs, leaves, flowers and fruit?
► The teacher introduces another phase of observation.
The pupils look for traces of animals in tree foliage: they examine leaves, noticing those with holes in them, half-eaten leaves and fruit that has been gnawed.
Under the tree they find feathers, fruit stones, hairs...
► If some of the pupils are agile enough and it can be done without risk, they could climb a tree and stay there a while, taking notes once they have climbed down.

What do the surroundings look like from up there?
► They also discover a smaller world of animals living within the foliage. Taking care not to disturb any concealed nests or holes, they listen out for sounds, and observe any movements of species: the buzz and hum of **pollinating insects** (bees, wasps, hornets), the flap of bird wings, rustling noises among the leaves.

► The teacher describes those ecological functions of ligneous plant foliage which have not yet been mentioned.
As well as being useful to humans as a windbreak or living hedge protecting crops and oases from erosion, tree foliage plays a vital ecological role:
• It lessens the force of the wind in arid regions, and so keeps soil from being lifted and blown away.
• The teacher briefly reminds the class of the part played by tree litter, the dead parts of the tree that have fallen to the ground where they decompose and enrich the soil with organic matter.
• The teacher points out that as well as providing shade for human beings and animals, even sparse tree cover provides the shaded environment that is essential for sexual regeneration: it protects the processes of flowering, pollen transportation, pollination, fertilization, fruit production and seed dispersal.
• Lastly, the teacher emphasizes the role played by tree canopies in improving microclimates. The shading effect produced by the reduction of the ambient temperature helps to reduce soil evaporation and lower the ground temperature.
Although there is little information available on this subject, it is clear that where there is no shade, the surface temperature of the soil can destroy dormant or germinating seeds on the surface. This prevents regeneration and accelerates desertification.

► The class then learns more about the part foliage plays in the growth and reproduction cycle of ligneous plants.
• In general, buds form at the axil of the leaf petiole and at the ends of branches.
Inside the bud are cells that will grow during the next growing season (in dry regions this takes place during the rainy season).
• In the case of deciduous trees the growth cycle corresponds to the leaf cycle.
Trees shed their leaves at the start of the dry season (except for *Faidherbia albida*). It is the drop in soil humidity which triggers leaf fall; when the rains return, more leaves appear.
Evergreens like myrtle (*Myrtus communis*) or Phoenicean Juniper (*Juniperus phoenicea*) keep their leaves all year round.
• Most buds produce leaves; others produce flowers and so mark the start of the tree's reproductive cycle, which takes place in the shelter of the foliage.
• Animal species that feed on parts of the tree canopy play an essential part in tree reproduction, as carriers and dispersers of seed.

► The pupils continue their mural: they extend the tree trunk upwards, adding branches from trunk to outermost twigs.
► They make the overall shape of the crown resemble a local species.
► They draw and then colour in a crown of leaves, taking care to use shapes and colours that are typical of their local landscape.

► Then, with the aid of documentation and real-life observation, they set about a detailed study of the animal species that live in the tree canopy.
► Depending on their region, they draw stickers showing **phyllophagous** (leaf-eating) insects such as the larvae of leaf beetles (*Chrysomelidae*) or the wattle bagworm (*Kotochalia junodi*), or **defoliating** caterpillars such as those of nymphalid butterflies found on *Salvadora persica*.

They include **frugivorous** (fruit-eating) insects such as beetles or weevils that may also appear in other parts of the mural. Arboreal reptiles are known to be fond of the fruit of the jujube (*Ziziphus mauritiana*, known as the iguana jujube).

► The pupils then concentrate on the species that play a part in the reproductive cycle:
• Bees, whose colonies are found in baobabs, help to pollinate them as they feed on the nectar of their flowers.
• Another carrier of baobab pollen is the fruit bat *Eidolon helvum*, which gathers pollen from the baobab flowers with its long tongue.
The pupils draw these as well as other local mammals that eat nectar or pollen, such as the nectarivorous phalangers of Australia which transport pollen in their fur as they climb trees.
• Some birds are also included, like the hummingbird which uses its long beak to siphon the nectar of tree flowers, covering itself in a thin layer of pollen dust.

► Lastly, the pupils focus on species that help with seed dispersal:
• They sketch birds that like to eat berries and seeds, many of which belong to the thrush family (*Turdidae*) in Africa and Arabia: thrushes, blackbirds, nightingales, and also wheatears such as the white-crowned wheatear (*Oenanthe leucopyga*), which often features in Tuareg stories.
• Other species expel stones and seeds in their faeces, the start of new trees. Giraffes, tall enough to reach the trees' fruit; and particularly elephants, which love to eat baobab fruit, providing the seeds with a soft bed of faeces that offer such perfect conditions for germination from where new plants will spring.

► Once complete, the tree mural is a magnificent sight.
It covers an entire wall and illustrates the 'ecological fabric' as well as the complete energy flows within its ecosystem.

52. Elephants,
shrubby savannah in the dry season, Niger
©Michel Le Berre

53. Elephant,
Aberdale National Park, Kenya
©Michel Le Berre

54

55

57

56

54. Baobab flower (*Adansonia digitata*), Kenya
©Michel Le Berre

55. Baobab fruits, W region, Niger
©Michel Le Berre

56. Finch nest, W region, Niger
©Michel Le Berre

57. Baobab bearing fruit, W region, Niger
©Michel Le Berre

► Looking at the main drawing, the stickers and the drawings in the margin, the pupils can really appreciate the scale and importance of the whole representation.
By producing such a quantity and diversity of biomass (as seen in the picture), and providing food and shelter for so many species (in the stickers), the tree takes its place at the very heart of the food web.
The annotated side drawings accompanying the mural underline the importance of the ecological functions of the tree.
► To conclude this activity, the class performs a role-playing exercise representing two points of view.
• The pupils perform a sketch and take turns to mimic the tree while acting out its qualities and benefits. Another pupil plays the role of a woodcutter with an axe; he/she is determined to cut down the tree.
• These two characters argue until the true cost of felling the tree becomes clear: there are many cases in which the tree has a key role, and actively contributes to the ecosystem balance; in such a situation, it seems that people stand to pay more by destroying it than by maintaining it.

05 An Inventory of Useful Plants

Level ★★
intermediate

Place
classroom
and outdoors

Duration
5 sessions

Objectives

1. Knowledge and comprehension

By using drawings to create a picture inventory, pupils will gain a full understanding of the direct uses of plants in many areas of community life.
The pupils are encouraged to ask questions about harvesting methods, plant use and, by extension, the consumption of natural resources.

2. Aptitudes

The teacher encourages pupils to engage in real dialogue with holders of local knowledge in the community.

Notes and suggestions:
For this laboratory workshop on the role of plants throughout their lifecycle, the pupils and teacher can use either a separate room or the back of the classroom.
They mount three large panels of paper or cardboard onto the walls, thereby creating an area for an inventory and plant display, a reception area, and an area for tasting and small experiments (pot plants, dyeing).
The teacher leading the activity takes a **holistic** view of the relationship between human beings and their environment (regarding the local population as an integral part of its ecosystem). Human activity, whether agricultural, industrial or commercial, has a considerable impact on ecosystems. We constantly receive a multitude of benefits and products from ecosystems which enhance our well-being and quality of life.
In this way, the ecosystem will primarily be regarded as a source of crops and bounty for humankind, a garden in the broadest sense from which the community picks its fruit.
The teacher may consider classifying the plants according to three themes illustrated by three wall panels:
A. The Nourishing Garden;
B. The Healing Garden;
C. The Protecting Garden.

Methodology

► The teacher divides the class into three groups of pupils, each responsible for one of the three panels in the inventory of 'plants useful to the community'.
Each group considers how its wall panel will be arranged. The ceiling height provides room for the pupils to hang specimens upside-down above each panel if necessary.
► The pupils begin classifying the plants according to their use:
• Food;
• Treatment, medicine and rituals (bodily health and spiritual well-being);
• Raw materials for building homes (protective cover for the family) and making clothes (individual protection).
Some plants have a number of uses and will therefore feature on several panels.
► In their groups, the pupils agree on how their wall panel will be arranged. With guidance from the teacher, they devise the sub-categories within each panel.

A. The Nourishing Garden

1. Classify

► The pupils conduct an initial classification of edible plants of the region according to the following categories:
• **Edible bulbs**, e.g. garlic, onion;
• **Edible stalks**, e.g. above-ground, fleshy stalks such as Barbary fig (*Opuntia ficus-indica*) and fennel, and underground stalks (tubers) such as potatoes;
• **Edible roots**, e.g. carrots and turnips;
• **Edible leaves**, e.g. common garden cress;
• **Fleshy fruits**:
– **Berries or seeded fruits**, e.g. jasmine berries, toothbrush tree berries (*Salvadora persica*), watermelon, courgette, African cucumber (belonging to the gourd family);
– **Drupes or single-seeded fruits**, e.g. dates, olives, jojoba and karite fruit;
• **Dry fruits**:
– **Pods**, e.g. the different varieties of peas and beans (belonging to the legume family), including pigeon peas (*Cajanus cajan*), tamarind (*Tamarindus indica*), cow peas (*Vigna unguiculata*);
– **Grains**, e.g. wheat, sorghum, millet, corn (belonging to the grass family);
– **Single-seeded dry fruits**, e.g. the kermes oak acorn.
In this way the pupils form an initial view of the **natural resources** available from plants, cultivated and wild.

2. Select one edible species

► Each pupil chooses a plant and is asked to identify it in its natural environment and sketch or draw it.
► If it is a common species, the pupil may bring a specimen into class. The pupil carefully takes a cutting and hangs it to dry (in the case of a grass, for example). The pupil may also try to replant a young shoot (a Barbary fig cutting, for instance).

3. Draw on the wall panel

► Each pupil then classifies the plant according to the above-mentioned categories and produces a full-colour drawing straight onto the wall panel.
The wall panel is divided into several sections corresponding to the various categories. The pupil takes care to place the drawing in the correct category.

58

58. Woman sorting wheat for cooking, *Altiplano* region, Bolivia
©UNESCO/Pierre A. Pittet

59. Farm worker and labourer, potato cultivation, Senegal
©UNESCO/Pierre A. Pittet

60. Traditional production of sun-dried tomatoes, Senegal
©UNESCO/Pierre A. Pittet

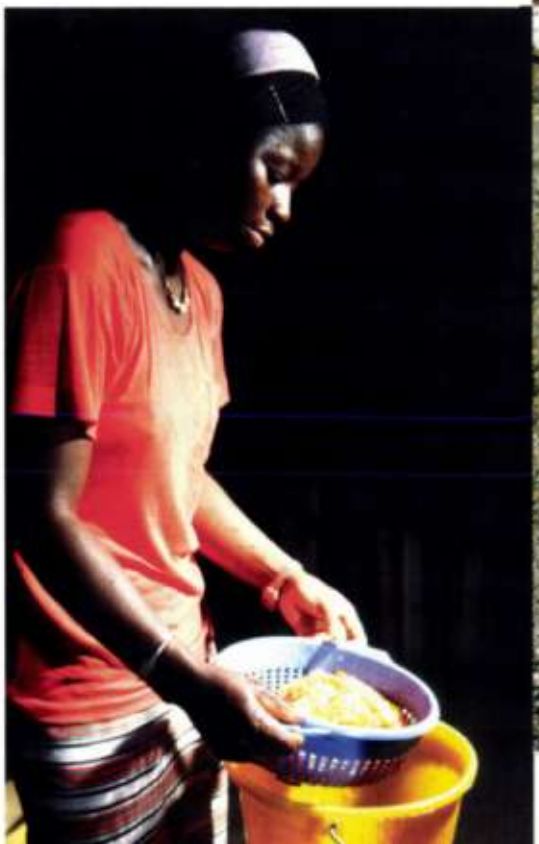
61. *Foggaras* system of irrigation, *Timimoun* oasis, Algeria
©Olivier Brestin

59

60

61

62



63

62. Traditional production of tomato concentrate, Senegal
©UNESCO/Dominique Roger

63. Women carrying water on their heads, India
©UNESCO/Bernard Henry

64. Women grinding millet, *Djenné*, Mali
©UNESCO/Alexis N. Vorontzoff

64

4. Taste

► While one pupil draws on the panel, another tastes or asks other pupils to taste the plant in question. For the purposes of this exercise, it is recommended that only well-known edible species are selected.
Blindfolding the pupils tasked with identifying the plant allows the teacher to test their ability to recognize flavours.
► The pupils may also bring food from home such as soup, fruit juice or samples of home-made recipes, which, owing to simple variants (such as cooking times or the inclusion of a particular herb), will allow them to rediscover the taste of a commonly used plant or one that, although well-known, has become increasingly neglected or under-used as it has become more rare.
Note:
The teacher's objective in this tasting exercise is to maximize opportunities to taste and identify the different flavours of well-known local plants (both commonly available and less so); in the case of wild plants, this could mean seeking increasingly rare plant specimens.

5. Seek and integrate information

► Back at the wall panel, the pupils add notes and information on the use of plants to their drawings:
• Is it a cultivated/wild plant?
• If cultivated, is it sown or planted?
• Is it eaten raw or cooked?
• Which adjectives can be used to describe the taste of the plant?
• Is it a common or rare species?
• If it is a naturally growing plant, has it become more rare over time? Is it possible to gather information on the **population growth** of a particular species?
• Is it an endangered and/or protected species?
• Does the plant contribute to nutritional diversification and development (by meeting specific nutritional requirements)?
Note:
It is important that these written notes be graphically incorporated into the wall panel, be positioned around the drawings, follow imaginary lines, vary in style depending on the sense and meaning and include symbols indicating whether a plant is rare or endangered.

6. Discuss local plants and food production with resource people

► At this point in the exercise the teacher encourages contact and interaction with at least two holders of local ecological knowledge:
• An elder (a respected member of the community) who has a good knowledge of local biodiversity as a source of complementary or replacement foodstuffs (and a source of income) in times of adversity;
• A farmer/breeder who understands the importance of cultivated plants in food production and the role of **indigenous plants** in conserving the local ecosystem.

► The teacher encourages the class to engage in dialogue with these local experts.
Discussions focus on the impact of the use and consumption of natural resources (particularly plants) on biodiversity and food security:
• Are wild plants becoming rarer in certain drylands?
• What are the consequences of this decline in (and sometimes **extinction** of) species for the nutritional health of the local population and their means of survival?
• How do land exhaustion (**monoculture**) and the alteration of natural habitats for agricultural or rearing purposes pose a threat to plant **conservation** and, in fragile ecosystems in particular, a region's food security?

• How are local biodiversity, and natural vegetation in particular, essential to cultivation and food production as a result of the functions they fulfil in the ecosystem?

B. The Healing Garden

1. Meet with an expert on plants and their properties

► The pupils pay a visit to the traditional healer or herbalist, the community specialist in essential oils and **medicinal plants.**

► The pupils ask the healer to take part in creating the second wall panel.

The pupils ask the healer to present plant samples to the class and may also, if allowed, go with the healer to pick samples.

2. Draw and record medicinal plants on the wall panel

► Based on the specialist's valuable input, the pupils classify the plants according to their therapeutic or healing properties, draw them in full colour on the wall panel and dry and hang specimens from the ceiling.

For the division of the panel into sections, the plants are classified according to their properties: tonic, antipyretic, purgative, diuretic, etc. Teachers may simplify this vocabulary and describe the conditions cured by the plants instead.

Examples:

In Africa, aniseed and fennel are used for many purposes. Giant fennel is a painkiller and a purgative (helps with waste elimination).

65. Desert oaks, *Kata Tjuta* region, Northern Territory, Australia
©Olivier Brestin

66. Termite nest, *Kata Tjuta* region, Northern Territories, Australia
©Olivier Brestin

67. *Eucalyptus caesia*, New South Wales, Australia
©Olivier Brestin

68. *Aloe vera* in bloom, *La Gomera*, Canary Islands, Spain
©Thomas Schaaf

69. *Eucalyptus annulata* flower, Western Australia
©Olivier Brestin

65

66

The bark of the baobab is antipyretic (reduces fever) and its leaves have a number of therapeutic uses, specifically diuretic (increases urinary secretion), tonic, and as a cure for dysentery and lumbago. They are also used in cooking as an ingredient in sauces.
The red flowered hibiscus (also known as *carcadet* or *bissap*) is a cultivated plant that produces an infusion rich in vitamin C (tonic).

3. Identify how healing and rituals are connected by plants

► The teacher introduces the sacred aspect of plants and encourages discussion.
Are some plants used in rituals? Are they used in initiation rites, healing rituals and the protection of particular areas?
The ritual use of each plant (for religious purposes or spiritual well-being) is described on the wall panel in the above-mentioned therapeutic categories.
Examples:
In some drylands, myrrh and incense are used in funeral ceremonies, and purification and sacrificial rites.
Other species, planted at the entrance of houses or surrounding them in order to afford protection, are used to mark territorial boundaries.
Sea squill bulbs (*Urginea maritima*) are used in the high Algerian plains as borders for agricultural plots.
► The pupils can enhance the information on the wall panel by drawing the rituals as they imagine them based on the anecdotes of the healer or herbalist. Here, as before, text and images work in visual harmony on the panel.

4. Explore the relationship between plants, cultural traditions and conservation

► Finally, the class explores the consumption of essential oils and medicinal plants and the impact of this consumption on the cultural traditions of healing and rituals.
• What non-destructive techniques can be used to pick precious wild plants?
• How can we ensure their conservation?

67

68

69

• Have there been cases of species extinction?
• What are the consequences for cultural traditions?
• To what extent does the herbalist or traditional healer's vast knowledge constitute the living memory of links between the various local plants and local culture?
• Can restoring local and indigenous knowledge in this particular respect contribute to the conservation of the ecosystem?
• Can the herbalist or healer transmit their knowledge across the generations via the classroom?
• Does the value accorded to certain plants naturally lead to the protection of specific areas?
• Are any of these areas recognized as **sacred natural sites**? Can these sites serve to inspire environmental conservation?

C. The Protecting Garden

As well as food, medicine and ritual ingredients, plants also provide shelter that affords protection and security. The use of plants as a building material for dwellings is the subject of the third wall panel. Locally, fibres and bark can also be used to make clothing, another form of protection, and may therefore also be displayed on the wall panel.

1. Make a sketch of one's own house

► The teacher asks the pupils to take a close look at their own homes and make a series of drawings and sketches on separate pieces of paper.
Do different types of dwelling exist within villages in drylands? Is there any evidence of a shift from a nomadic lifestyle to a more settled one, or of an alternation between the two lifestyles among the population?

2. Draw a typical local dwelling on the wall panel

► The class compares the various drawings and chooses one that is representative of each type of local dwelling.
The chosen drawing is then re-drawn on a bigger scale on the wall panel.
► Other pupils use words and arrows to identify and clearly label the plants that the houses are made of (for each dwelling type drawn on the wall panel).
For nomadic dwellings:
• What is a tent made of? Is it made entirely of animal materials, such as goats hair or cow, goat or camel hide? What are 'yurts' or '*gers*' made of? (common in central Asia and still widely used by nomads in Mongolia).
• Is the nomadic dwelling easy to dismantle, such as a matted straw or latticed panel hut? Which plants are used?
For sedentary dwellings:
• Even if the hut is made of stone or clay (often called *banco*), are plants also used in its construction?
• What is the roof covering made of?
Example:
Thatched roofs, sometimes made of date palms but more often with grasses such as typhas (*Typha australis*) as found in Senegal, Algeria and Mauritania.
• What kind of wood are the main beams made of?
Which types of tree are most commonly used for this purpose?
Example:
The date palm is commonly used, but if it is not available, which tree species are used instead? *Acacia tortilis*? *Acacia radiana*? If these tree species are rare, are any other tree species used?
• Are there any sedentary dwellings made entirely from plant materials?

70. and **71.** House and village, Dogon Country, Mali

70 71

Examples:
Circular structures made from grasses are typical of some African regions.
A *zeriba* is a lightweight construction that can be made with different plants – straw, for example, or braided or woven foliage.

3. Depict the dwelling in detail

► Still focusing on the depiction of the dwellings, another group of pupils produces detailed sketches of the main picture, highlighting the detail of the construction by drawing 'close-ups' of braids and fixing points or producing a series of sketches showing the stages of construction.
► They write down the names of plants that are made into rope or thread in order to tie or fix items together.
Examples:
Sisal (*Agave sisalana*) is a fibre extracted from the leaves of the agave, found in South America.
Needle grass (*Stipa tenacissima*) is common in the Mediterranean basin and in northern Africa.
Gamba grass (*Andropogon gayanus*) is found in Sahelian Africa.

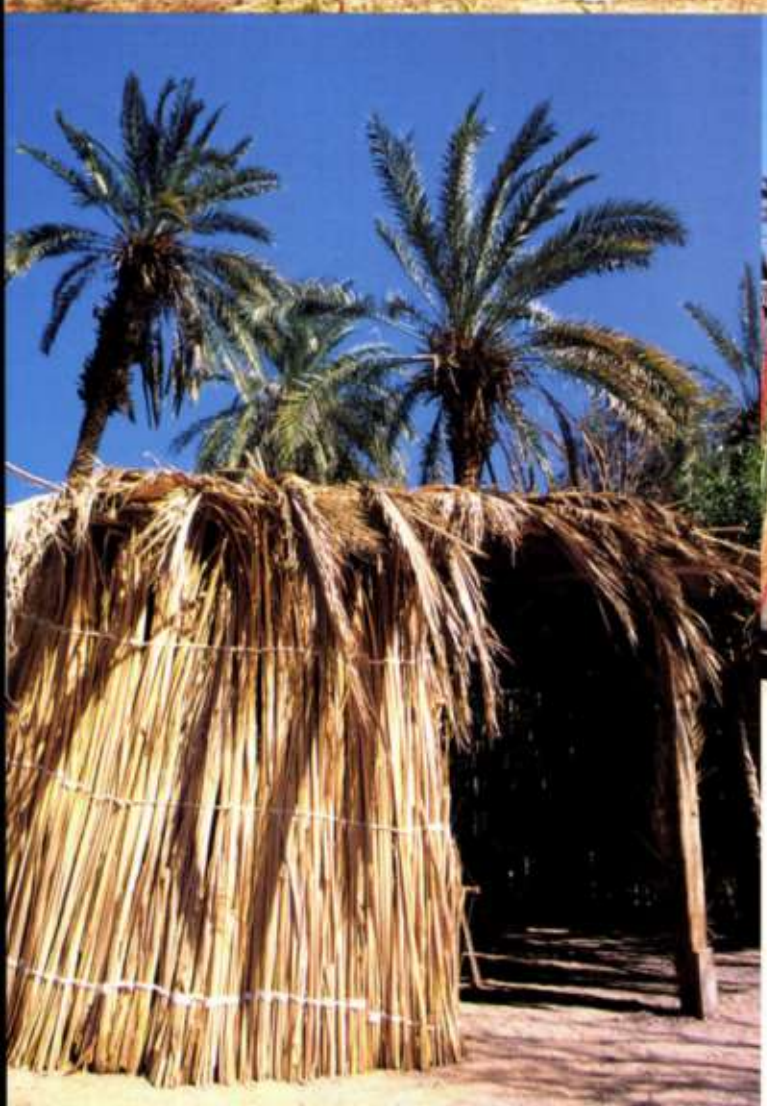
4. Make the connection between environmentally-adapted dwellings and natural resources

► The pupils describe the characteristics that show how the plants have adapted over time to the environment and climatic conditions.
The population has learnt over time how to make use of these characteristics by developing sophisticated, highly specific uses for the plants, for instance in the construction of dwellings.
- Which plants are best at providing shelter from the wind?
- Which plants are insect-resistant?
- Which plants protect from extreme heat and dryness?

Example:
Palm leaf spines arranged side by side allow air to circulate freely and keep the inside of the dwelling cool.
The information is either written or drawn directly on the wall panel.

5. Conduct an overview of how plants are used in the construction of dwellings

► Finally, the entire class discusses the important role of plants in improving the living standards of dryland inhabitants.
Wood is collected for house shells and for general construction (such as *Acacia albida* or *Gao* in Africa).
It is also collected for handicraft and furniture making. But these various uses, along with the collection of **firewood**, also represent one of the main causes of the **deforestation** that is largely responsible for the rarefaction and disappearance of the plant cover.



72. Huts and isolated trees, Guinea
©Michel Le Berre

73. Tuareg shelter,
Tassili N'Ajjer, Algeria
©Olivier Brestin

74. Tuareg tent, *Djanet*,
Tassili N'Ajjer, Algeria
©Olivier Brestin

► The teacher encourages the pupils to reflect on the following questions:
Despite the ever-increasing need, could it be possible to promote action and encourage behaviour to curb or limit this trend?
What non-destructive methods can be used to harvest wood from trees while maintaining the forests?
• Using traditional wood-cutting techniques:
Example:
Selective **pruning** and trimming.
• Encouraging the conservation of natural resources through the selection and rational consumption of species according to need:
The teacher demonstrates how, by its very nature and the many different functions it fulfils, species diversity meets the specific needs of the population.
• Promoting natural regeneration:
Re-sowing, creating plantations and maintaining forests; avoiding cutting down young trees and shoots; controlling pasture zones by delimiting the perimeters of protected areas; providing alternative, renewable energy sources such as solar power.
► Finally, the teacher may consider the advantages and drawbacks of modern, urban building materials.
Examples:
Cement and steel are industrially produced and sturdy. However, they are costly and consume both water and energy.

Guidelines for more advanced work:
At various stages in the activity, or once it has been completed, it would be a worthwhile exercise to combine this primarily visual and pictorial inventory with more scientific ones which have been compiled as part of national or regional action programmes in countries that have ratified the **United Nations Convention to Combat Desertification** (UNCCD).
With regard to the monitoring and evaluation of biodiversity, teachers are encouraged to consult scientific databases such as the **GTOS TEMS** database, which provides an analysis of environmental quality indicators at sites around the world, the BRIM (**Biosphere Reserves** Integrated Monitoring) initiative which is managed by **UNESCO**'s Man and the Biosphere (**MAB**) Programme and the **IUCN** Red List of Threatened Species, the world's most comprehensive inventory of the global conservation status of plant and animal species.

75. Argan plantation, *Sidi-Bel-Abbès* region, Algeria

06 The Plant as Mascot

Level
advanced ★★★

Place
classroom and outdoors

Duration
6 sessions

Objectives

1. Knowledge and comprehension

After *An Inventory of useful plants* (see Chapt. 2, act. 5, p.96), the pupils focus on one particular plant and designate it as a mascot by showing and celebrating the services it provides in the everyday life of the population.
Part of this study focuses on the traditional use of wild plant species in the making of products that typically represent the local cultural heritage.

2. Aptitudes

As a result of their discussions in class, the pupils learn enough about managing the natural resources of their home territory to debate the subject with environment professionals and other resource persons at a specially organized meeting.

Notes and suggestions:
This activity can be carried out at two levels. The teacher splits the class into two groups.
The first group (the intermediate level) chooses a common plant as a mascot (in many cases a cultivated one), which is unquestionably a source of income for the population. It may be a plant associated with the identity of a region or country.
Examples:
Africa, Arab countries: the date palm (*Phoenix dactylifera*) or other 'cultivated' palms such as the doum palm (*Hyphaene thebaica*) or the African Palmyra palm (*Borassus aethiopum*).
In Central America, the Barbary fig (*Opuntia ficus-indica*) originating from the arid and semi-arid regions of Mexico, is now widely cultivated.
The second group (the advanced level) selects and finds out about a wild plant that grows naturally in the local environment but which is less accessible. The elders of the community remind us of their uses and benefits. Choosing a plant like this gives the pupils the means of readily appreciating the degradation of the natural flora as well as highlighting the role played by traditional knowledge in the conservation of forest and other plant resources.
Examples:
Pupils may choose a fairly widespread plant such as the desert date or soap berry tree (*Balanites aegyptiaca*) which is found throughout the Sahel, the Middle East and Pakistan; or a plant found frequently in some dryland regions and less so in others, such as the jujube (*Ziziphus mauritiana* or *Ziziphus spina-christi*), the tamarind (*Tamarindus indica*); or even a plant which, though widely recognized and valued, sometimes has difficulty reproducing in the wild (*Adansonia digitata*, *Combretum micranthum*, *Commiphora africana*).

76. From left to right and from above to below:
Palms (*Washingtonia robusta*): petioles, crown and dry wilted leaves, weaving with palm leaves by a *Tarahumara* woman, hats and roof made from palm leaves, Mexico









Methodology

1. Research, observe and draw the plant

► With the teacher's help the pupils find out about the plant they have chosen: its origins, geographical distribution and general symbolism in their own and other cultures.

Example:

The date palm (*Arecaceae family*) has been cultivated for thousands of years. It originated somewhere between the Persian Gulf region and western India, and is now common in North Africa and the Middle East. It is associated with the ecosystems of Saharan oases, which are still sometimes used for traditional agricultural production and form a respected part of the cultural and ecological heritage.

In Mediterranean culture, steeped in Graeco-Roman heritage, the palm is the very symbol of victory.

When **native species** belonging to the same botanical family are found in more than one continent, it is well worth getting the pupils to compare them and draw parallels between the species.

Example:

The *Arecaceae* family also includes the fan palm from the *Washingtonia* genus, including the two species *Washingtonia robusta* and *Washingtonia filifera*. Colonies of these grow in the damper gorges and canyons of arid regions in north-western Mexico.

This kind of parallel observation could also provide a good opportunity for swapping views and facts with other schools from different dryland regions of the world, by sending the notebook compiled by the class to other partner schools of **UNESCO's Associated Schools Project Network** (ASPnet).

► Next, the pupils draw pencil sketches of the plant, bringing out clearly all its distinctive characteristics:

• In the case of the date palm, a crown of finely divided pinnate leaves, a stipe that is rather thin in relation to the size of the tree, a long petiole at the base of each leaf, and very long female inflorescences heavily laden with fruit (the species is **dioecious**: each plant has only male or only female flowers).

These are all aspects that should be noted and can easily be drawn.

• The same applies to the tennis-racket shaped **cladodes** (commonly known as 'nopales') of the

77. From left to right: Prickly pear crops (*Opuntia ficus-indica*), fruits on the stem segment of the prickly pear, stem segment (*nopalitos*) and cooked nopales, water salad, and a dish made from nopales and water salad, Mexico

Barbary fig (*Opuntia ficus-indica*). These are clearly defined elements, just as obvious as the flowers or fruits. A fertile cladode can carry up to 30 fruits, depending on its position and orientation on the plant – a detail well worth including in the drawing.
The chosen plant's most familiar physical or morphological characteristics should also be shown in a drawing or a model: the multi-branched, spiny appearance of *Balanites aegyptiaca*, its unusual green colour (which can be depicted by painting); the great girth of the baobab's trunk (*Adansonia digitata*) and its root-like branches. Such features serve to emphasize the mascot, to 'totemize' the plant and represent it in many different ways.

2. Taste and savour the plant in all its forms

► Recalling the 'nourishing', 'healing' and 'protecting' gardens of the previous activity, the pupils identify the mascot plant's various uses:
• for human and animal food or fodder;
• for human or animal health;
• for energy requirements;
• for building and crafts.
It is important that the mascot plant should be part of the human diet, because food is primordial in human cultures. In arid regions this has always been especially true of all kinds of culture: pastoralist/herders, hunter-gatherers, and farmers.
► With advice from their families and the guidance of the teacher, the pupils bring various ingredients to school and make sample dishes and preparations using the mascot plant.
• In Latin America pupils who choose the Barbary fig can bring and taste fresh, ripe fruit, fig jam, as fructose sugar or in the form of a drink, young nopales known as 'nopalitos' which are cooked as a vegetable or prepared in a salad and, in some cases, honey from the flowers of this plant, which are very popular with domestic bees.
• In North Africa, for example, they bring dates, the fruit of the date palm, in every form: fresh dates, fermented dates, dried dates, dates in jam, date sweets, vinegar from fermented dates, and oilcake made from ground date stones for cattle.
They may bring in palm wine, and roasted palm seeds for a kind of 'coffee'.
The same can be done with wild species.

• *Balanites aegyptiaca*, for example, can be represented by its bittersweet fruit (sucked as a substitute for dates), its young leaves eaten as a vegetable or as a sauce for pearl millet, in the form of butter made from the sheath of the fruit and often mixed with shea nuts, or in the form of a fritter dough made from the leaves.

► The pupils realize that all these food uses and tastes come from a single plant!
This exercise is a continuation of *An Inventory of Useful Plants*: it takes one particular plant, and links it to the whole range of its associated products and tastes.
► The various edible samples (except the cattle feed) are displayed on a table in the form of an exhibition.
► The pupils prepare written texts in which they describe the preparations and recipes, as well as their own experience of tasting the different dishes. Words to make the mouth water!

3. Discover the nutritional value of the mascot plant

► At this stage, the teacher provides some essential information:
People have shown great ingenuity in developing uses for some remarkable species in our ecological heritage, of which there is a proportionately restricted number in dryland regions. That ingenuity is a fitting counterpart to the great range of qualities offered by these species.

78. Baobab (*Adansonia digitata*)
© UNESCO-MAB

79. *Balanites aegyptiaca* (detail), *Air* region, Niger
©Michel Le Berre

80. *Balanites aegyptiaca* (sometimes called 'desert date'), *Air* region, Niger
©Michel Le Berre

80

79

► The pupils are then asked to note the nutritional qualities of their mascot plant – in many cases these will be exceptional.
► Here the teacher tries to contact and talk with an expert in local plants and dietetics.
• The amount of vitamin C contained in an orange is 57mg/100g, whereas the baobab fruit provides 360mg/100g and the jujube fruit (*Ziziphus mauritiana* also known as *Ziziphus jujuba*) 1000mg/100g.
• The leaves of *Balanites aegyptiaca* contain 3700mg of calcium per 100g. A few dry baobab leaves (*Adansonia digitata*) – approximately 33g – provide all the calcium a person needs for one day.
• Baobab leaves are also rich in protein and are often eaten fresh, as young shoots. They are so nutritious that they are preserved by drying, and used to season various sauces. A smart use of seasoning!
• Baobab fruit pulp produces drinks rich in vitamin B1, while the flour made from the seeds is up to 48% protein – highly recommended for small children! If the pupils can compare notes, they will learn that a flour with similar qualities is prepared from the very nutritious fruit of the *Washingtonia filifera* palm in Mexico.
► So the pupils study the nutritional role of their mascot plant, and write small labels giving details of the samples on display.
• When is the best time to eat it?
• What other foods go well with it?
• Can its food applications be further developed? Can they be more accurately understood?
• Can it help to prevent infant malnutrition?
• Is it a useful complementary food – like the gum arabic from the *Acacia senegalensis* or *Acacia nilotica* which is a basic food for bush gatherers but could find a much more widespread use as a complementary food, since has the property of enhancing vitamin synthesis?









81. From left to right and from above to below:
Chandelier cacti (*cardones*), roof structure, door and traditional objects made from chandelier cacti stems, *San Pedro de Atacama* region, Chile

• Can the mascot plant be used as a substitute food in times of famine? Can it be packaged and preserved? Is it sufficiently drought-resistant?
► Guided by the plant expert, the teacher takes the opportunity to review what has been learnt about substitute foods.
These foods are often unattractive compared with the leaves and fruit that people normally gather, since they require complicated soaking and cooking procedures; but it is vital to recall their existence here, and teach the class how knowledge about such foods has evolved, together with their use.

► To conclude this section, if the class has access to a camera the pupils take photographs of their exhibition: close-ups of the individual sample dishes, and wider shots of the whole exhibition, carefully labelled and annotated.

4. Highlight the plant's other uses: craft applications

► With the teacher's help the pupils continue to identify and display the plant's services to humans. In each case they work out the best way of illustrating how the plant is used by explaining the procedures involved, the skills required, and the results.

► The pupils begin to appreciate the process elaborated over time in the use of traditional plant resources for construction and other crafts.
People choose one plant rather than another because of its specific qualities. When there is plenty of vegetation they choose one particular species out of several, for the density or hardness of its wood, the properties of its **exudate** or resin, or its **tannin** content.
The pupils make the connection between their mascot plant and the objects and substances obtained from it, and relate their specific properties back to the plant.
• *Balanites aegyptiaca*, a tree with hard, solid, rot-proof wood, is used to make beams and everyday tools such as pestles, or handles for axes and knives, or digging tools like the iler.
• *Commiphora africana*, from the *Burseraceae* family, is used to make big objects such as saddles for dromedaries or horses, and also milking bowls; the wood is ideal for furniture and large objects generally because its low density makes it light and easy to handle and carry.
• The *kinkeliba* (*Combretum micranthum*) gives a wood that is easy to work, and is used to make smaller, more finished items like chairs or frames and fittings for beds.
Every object corresponds to a particular species or particular qualities of wood, which is general knowledge among the local population.

► The species chosen by the pupils will be an even better mascot if used to make a whole range of different things.
• For example, *Balanites aegyptiaca* is also used in the production of soap, which is obtained by soaking the kernels and strips of bark in water and then rubbing them.
• Soap can also be made from olive oil (*Olea europaea*). The technique and manufacturing process have been investigated as part of the international scientific project **SUMAMAD (Sustainable Management of Marginal Drylands)**, and developed by the research unit at the *Dana* biosphere reserve in Jordan, one of the project's nine sites.
• The resin of the gum tree *Commiphora africana* (mentioned above) yields a glue, and also an incense.
• *Commiphora africana* is used in many social and cultural activities, from craft manufacturing to rituals involving the burning of incense to stimulate religious feeling.

► From their homes the pupils bring in articles, utensils, cleaning materials, cosmetics, medicines or cult objects made from their mascot plant, so as to display them (however briefly) alongside illustrations of the plant itself (sketches, paintings, photos) and diagrams to explain the manufacturing processes.

► The teacher stresses the importance of displaying the finished item, the processed material and the source (i.e. the plant in its natural state), alongside each other.
The object is part of a cycle; there is a three-way relationship here, between:
– nature;
– humans, whose minds and hands have shaped and finished the article with a view to using it and handling it daily;
– the object itself, whose manufacture brings humans and nature together.

► Then the teacher asks some questions:
Are objects or materials made using local knowledge and local resources sometimes preferred to those that have been manufactured industrially?
• Providing hand-grinding is not a daily chore carried out by women such that it deprives them of time otherwise spent at school or training – does hand-ground flour taste better than industrially milled flour?
• Which tastes better, milk kept in a wooden bowl or calabash or milk kept in a plastic or metal container?
Many African pastoral groups process milk in containers of vegetable origin, keeping strict standards of hygiene. The calabash comes from a cucurbitaceous plant, often the bottle gourd (*Lagenaria siceraria*).

5. Examine how the mascot plant is harvested locally

► The teacher summarizes the facts assembled so far:
• Traditional knowledge can contribute to the preservation of biological diversity since it promotes coherent, meticulous and well-adapted use of local plant resources, according to the needs of the population. So how is the exploitation of these resources to be organized so as to safeguard and improve everyone's welfare?
• When there is no longer a balance between the needs of the population and the regenerative capacity of natural resources, then traditional knowledge, which protects biodiversity, is thrown aside.
► The teacher continues:
In many dryland areas this balance has been upset by several factors:
– demographic pressure is constantly rising and results in increased demand;
– climate change has aggravated drought in recent years;
– the abusive exploitation of trees for firewood and fodder is a particularly damaging **anthropic** (man-made) problem.

► At the teacher's suggestion, the class considers:
Is the mascot plant used as firewood or is it a source of fodder for cattle?
The majority of mascot plants mentioned in this activity will correspond to one of the uses.
Examples:
The stipe of the date palm, which provides excellent wood for rafters or doorposts, is also a very widely used fuel in regions where trees are rare.
In some parts of Central America farmers are using the Barbary fig all year round to supplement their cattle's diet, since the nopals are rich in protein.
► The pupils note that the same is true of wild mascot plants: ligneous species provide crucial additional fodder for cattle when herbaceous plants are rare and of little nutritional value.

82. Olive plantation (*Olea europaea*), *Khanasser* valley, Syria
©Thomas Schaaf

83. Group of young school children, *Khanasser* valley Syria
©Hélène Gille

84. Soap bars made from olive oil, *Dana* Biosphere Reserve, Jordan
© RSCN, Jordanie

85. Olive tree planted in a dug-out basin in the soil, Syria
©Thomas Schaaf

86

88

87

86. Intercropping barley with associated *Atriplex Halimus*, *Khanasser* valley, Syria
©Hélène Gille

87. Farmer holding an *Atriplex Halimus* plant, Syria
©Hélène Gille

88. Transplanted *Atriplex Halimus*, *Khanasser* valley, Syria
©Hélène Gille

Examples:
In Sahelian Africa, the pods of the *Acacia albida* (*Faidherbia albida*) make up 30 % to 45 % of fodder and are fed to frail animals, and sold in the region's markets for their fortifying qualities.
Cattle enjoy eating the leaves of the soap berry tree (*Balanites aegyptiaca*), and it is often pruned for fodder.

► The teacher moves steadily on, and gets the pupils to consider the harvesting of the mascot plant by the local population.
What is the situation on the ground?
In many cases the plants are being harvested faster than they can regenerate.

6. Identify forms of plant removal, production and distribution which damage the ecosystem

► The teacher goes back to the species used earlier as examples and describes cases where plants (*Balanites aegyptiaca*, for instance) are cut several times in a single season, losing virtually all their foliage.
• Such cropping is bad for the conservation of the species: it has to cope with being cropped for several purposes and is subjected to excessive pressure.
So the regeneration of entire plant populations is now under threat.
This is true of *Balanites aegyptiaca*, which is pruned or stripped for human consumption, animal fodder, firewood and charcoal production.
► The teacher reaffirms this observation:
It has become a rarity to find a specimen of *Balanites aegyptiaca* with a good broad trunk.

► The pupils note other distinct points:
• Some other instances of harvesting directly harm the individuals that make up the species.
If all the bark is stripped from the trunk of a tree such as *Adansonia digitata* or *Acacia seyal* to get the fibres for making rope, this leaves the plant vulnerable to the arid climate, to insect attack, and to difficulties of water supply (the xylem is damaged, and in the end the plant dries out).
• Finally, some forms of harvesting are directly harmful to ecosystems.
For charcoal production, for example, trees are harvested indiscriminately; most of the species that were present to start with are liable to disappear. When harvesting is intensive and widespread, not only does the amount of biomass decrease, but so do genetic diversity and the number of different species.
Some species such as the baobab find it hard to regenerate because they no longer benefit from the lower-level plant cover of low-growing plants and prickly bushes.

► If the mascot plant is a cultivated species, the teacher asks:
• Has it been introduced in a sustainable way?
• Has the land under cultivation been extended in order to grow the mascot plant?
• Have forest resources or even an ecosystem been destroyed in order to cultivate it?
Example:
In some parts of the Sahel the striped tiger bush ecosystem is retreating in the face of the development of various food-producing crops here and there in the countryside.
• In the case of an intensively-cultivated cereal plant, has care been taken to plant it in association with a perennial species, promoting **intercropping**?
Example:
The Syrian site of the SUMAMAD project mentioned above, managed by the **International Centre for Agricultural Research in Dry Areas (ICARDA)**, is actively researching the intercropping of barley with the perennial **halophyte** species *Atriplex halimus*, which helps to protect the cereal crop from drying winds and keeps the soil in place. Growing both species together provides more available fodder and can also enhance species diversity.

► The teacher concludes with a final series of questions:
Is cultivation of the mascot plant spreading within the ecosystem in a sustainable way?
• Is the species grown from a **cultivar** – produced using horticultural techniques and not to be found in the wild population ?
• Is it a foreign species, one that has been introduced here outside its original distribution area?
• If so, is its spread within the ecosystem under proper control?
An invasive foreign species is one that is introduced and then grows and spreads so rapidly that is competes with **native species** and can be hard to control, particularly if the new ecosystem lacks the predators or pathogenic agents of the invader's homeland.
Example:
The Barbary fig, a large perennial cactus, can spread quickly through the countryside; in the past, as an introduced species, it has sometimes really 'infested' the ecosystems of some parts of Australia, West Africa and South Africa. The only means of slowing its proliferation has been biological control, by introducing parasites
.
► The last question considered by the class in this critical investigation stage is:
Can the mascot plant truly be considered a mascot if its removal, production or distribution in the ecosystem is non-sustainable?

7. Meet the people who work on the environment and lay the foundations for a joint project for sustainable natural resource management

► Now that the class has reached the stage of asking this question, it sets up a meeting (at the teacher's suggestion) with the community's various resource persons, stakeholders and decision-makers: farmers, herders, foresters and craft workers, for example, as well as scientists, forestry experts and agricultural engineers.
► The pupils show their exhibition to these people whose work involves the environment, and explain what it represents. They take them round the various displays relating to the mascot plant.

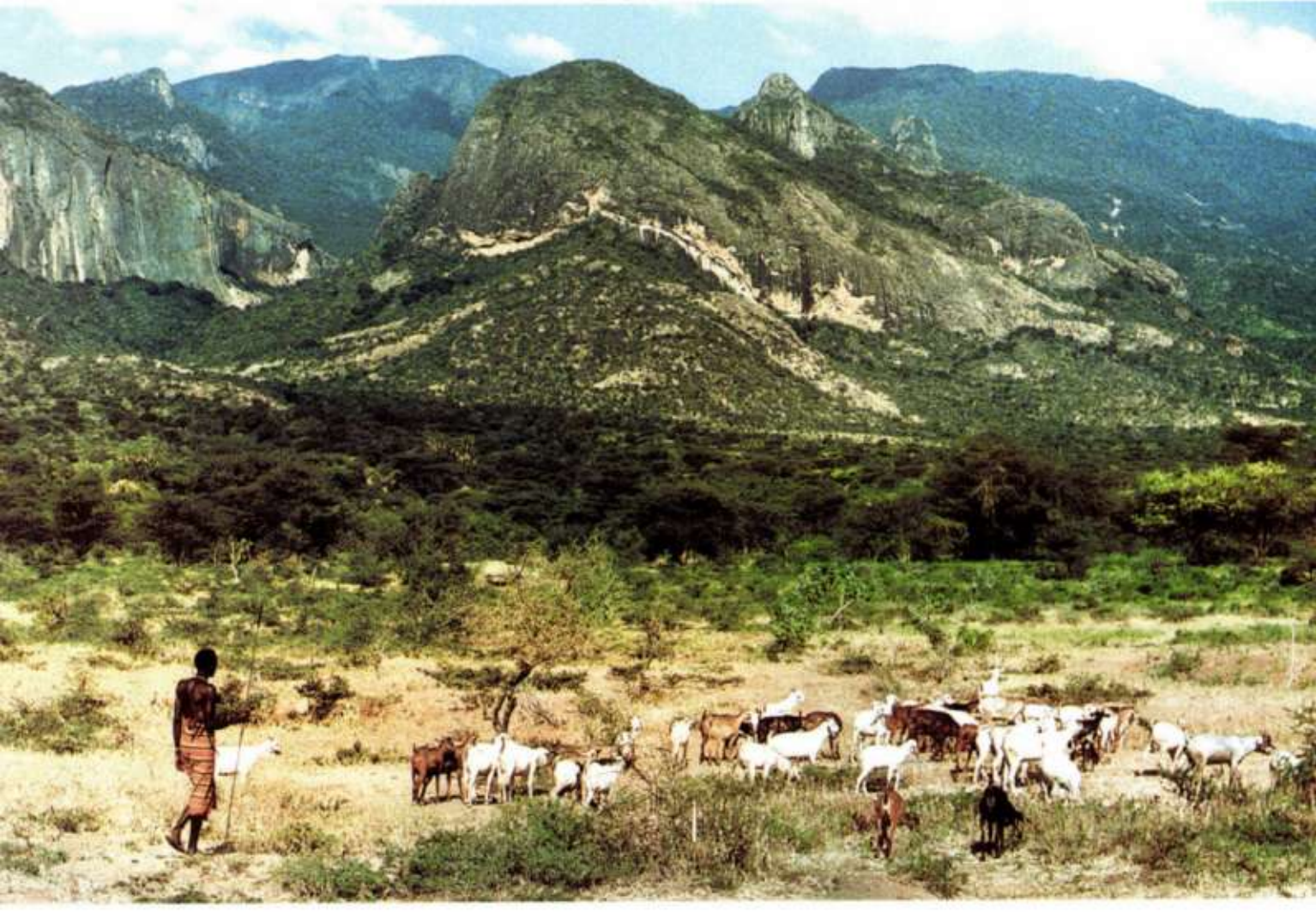
► This working group – pupils, teachers and resource persons together – discusses the various factors and forms of behaviour that lead to irresponsible management of natural resources, and especially mishandling of the mascot plant.
► Each of the groups involved explains its point of view:
• Nomadic herders, who in Africa often have a cash-generating sideline in charcoal-burning as well, have a heavy demand for wood.
• Pastoralists with large flocks and herds are always on the lookout for herbaceous biomass. In the dry season there is little grass on which to graze, so they 'make do' with tree foliage to feed their animals. They also allow them to graze in cultivated fields, which harms the farmers' interests and quickly leads to conflict.
• Foresters want to maximize the regeneration of ligneous species.
• To farmers, the soil is their livelihood; they are directly affected by the consequences of land degradation and changes in climate. They often see their fields trampled by flocks and herds, or the soil impoverished through the disappearance of species with important ecological functions. They themselves cause species extinction and desertification when they cultivate or use land inappropriately (over-extended cultivation, too little land left fallow, monoculture).
• The attitude of settled village populations is also important. They go wood-gathering and take large quantities from the same places, too near the village. They often decimate resources for their own immediate advantage.

► The participants in the discussion agree in front of the class to draw up a joint project laying the foundations for a solution that is fairer to everyone, and more sustainable (see the next activity: *The experimental garden*, p.120).
The debate is moderated by the scientists with the help of the teacher and the class.

► Together, the working group tries to work out answers and suggest solutions for many questions, some of them acute.
A few are mentioned here:
• Will it be necessary to establish new plantations of the mascot plant if its numbers are to be maintained?
• Should the number of domestic animals in the local ecosystem be limited, to prevent overgrazing?
• What other solutions might be considered?
• Does ecological management depend on land management?
• Should there be separate demarcated zones for stock-rearing (a pastoral zone where grazing and regeneration of herbaceous ground cover would be given priority), for the development of forest resources and wood production, and for cultivation?
• Should pastoral corridors be made for shepherds and their flocks?
• Should there be special zones for gathering rational quantities of the things people need (fruit-picking, firewood, timber, fibres)?
• Should a certain percentage of trees be protected in cultivated zones?

- Should there be special efforts to avoid monoculture and introduce a suitable rotation of crops growing in the shade of the trees?
- Should there be restrictions on extending cultivated areas?
- Should there be restrictions on the planting of cultivated ligneous species?
- Should the planting of introduced species be restricted and monitored over time?
- Should **perennial species** be reintroduced?
- Should **spontaneous vegetation** be maintained by setting up integrated conservation zones within the various ecosystems?

89. Herder with his herd of goats, Sahel



07 The Experimental Garden

Level ★★★
advanced

Place
outdoors

Duration ●●●
Over several seasons as the plants grow, patience is a virtue...

Objectives

1. Knowledge and comprehension

As part of the United Nations **Decade of Education for Sustainable Development**, pupils develop, over several years, an experimental garden for the whole school, a testing ground for several activities relating to environmental protection.
They learn about the functions of perennial plant species and how to use them for the conservation of natural, semi-natural and agricultural ecosystems.

2. Aptitudes

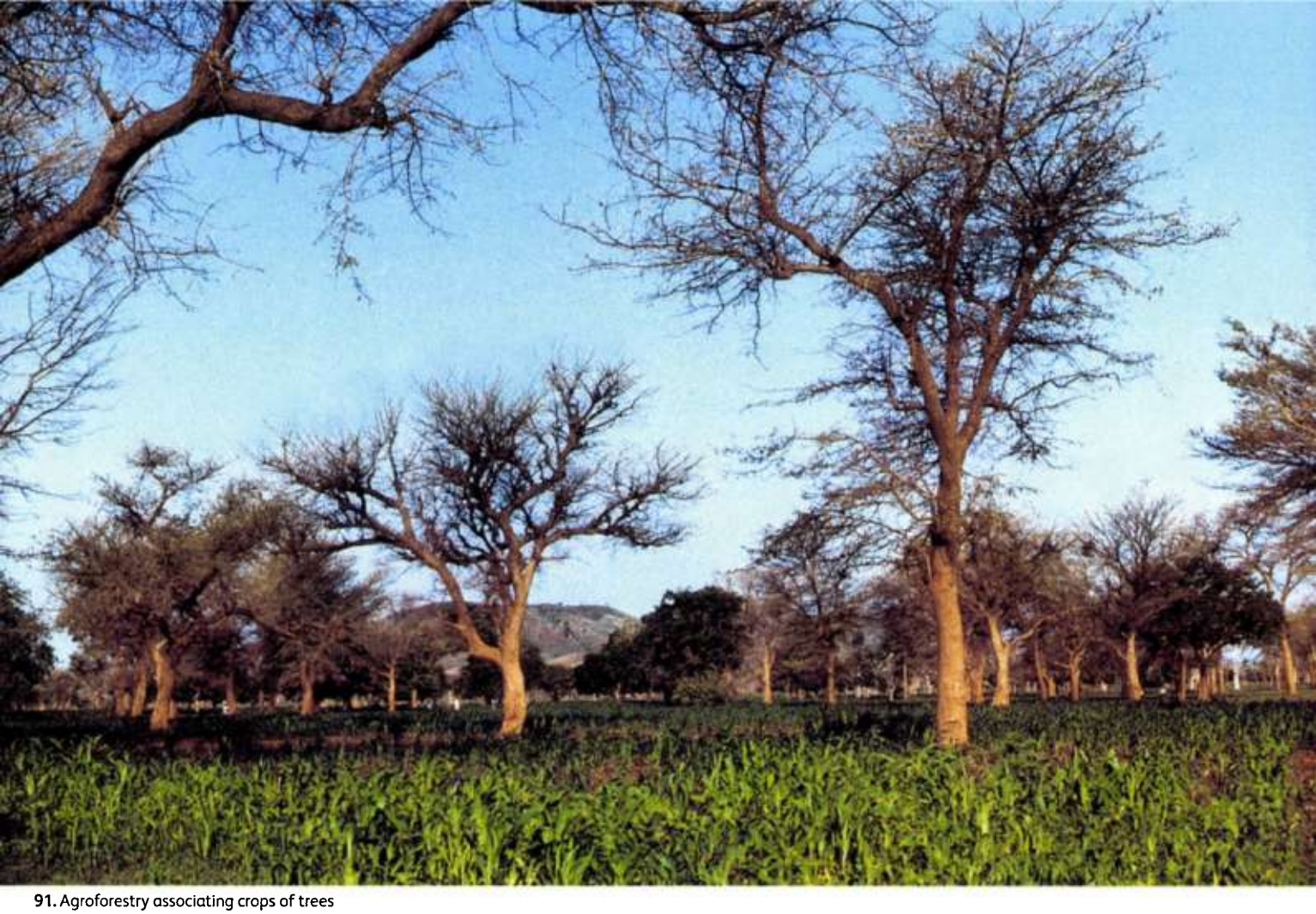
Pupils acquire practical and technical skills in gardening and agroforestry, and gain the theoretical knowledge to validate their practical experience through contact with those who are professionally engaged in working with the environment.

Notes and suggestions:

For this activity we particularly recommend setting up a team of several teachers, maybe even involving more than one school. Starting with an introduction to the basic principles of environmental protection, the teachers will develop a practical teaching project based on this garden, putting the concept of **sustainable development** into action and placing it at the heart of the project by teaching the pupils how to take long-term action that will benefit them in future – and not only them, but other pupils and other generations as well.
The experimental garden is a natural continuation of the land management programme begun in the previous activity. It should therefore be linked to the various sites chosen by local decision-makers for pilot environmental protection actions. The schoolchildren will go back and forth between the testing ground (their experimental garden) and the full-scale areas cultivated by professionals.

90

90. Low plants crops among the palm trees, *Béni-Abbès*, Algeria



91. Agroforestry associating crops of trees and herbaceous species, Sahel

Methodology

1. Understand local environmental protection initiatives

► The teachers consult with those whose livelihoods involve the environment (community decision-makers, farmers, herders, foresters, knowledgeable or influential individuals, engineers, students and other teachers). The team of teachers finds out about the environmental protection initiatives taken following the launch of the land management programme whose basic principle and ideas have been agreed earlier.

There is a wide range of possible initiatives:

- To improve the yield of annual crops by intercropping them in association with edible perennials (from the wild or in their natural habitat) that possess various ecological functions;
- To fertilize a poor, stony area of land by introducing **nursery**-grown trees, and through horticulture;
- To regenerate forest resources and create a zone for the rational harvesting of forest products for the population: firewood, fruit, seeds and medicinal plants;
- To regenerate the herbaceous layer and develop pasture for animals in a zone reserved for livestock;
- To develop a controlled zone for the production of wood for building and other uses without exhausting natural resources by land-clearing and felling;
- To use **agroforestry** methods to introduce crops in forests without having to cut down trees;
- To prevent the sanding up of **oases** and to stabilize dunes using a system of **windbreaks** or greenbelts composed of plantations of various grasses, shrubs and trees.

92

93

92. Women farmers drying *Atriplex halimus* seeds, *Khanasser* valley, Syria

93. Scientific experts of the SUMAMAD project in the plant nursery, *Khanasser* valley, Syria

All these involve planting or sowing particular species and knowing how to maintain, select and use perennial plants (edible and non-edible) that are particularly adapted to the various conditions found in arid ecosystems.

► The teachers receive training from the environment professionals. They learn how to enrich the soil, to make **compost**, to select seed, to tend and transplant plants, to create a school nursery and to look after a wild orchard.

Example:

As part of the activity conducted by the SUMAMAD project's Syrian site in the *Khanasser* valley to facilitate close cooperation between local authorities, farmers or herders and ICARDA scientists, the members of the community involved might be willing to transmit some practical expertise to a team of teachers.

With the help of 'facilitators' who provide a link with the farmers and explain the benefits of the experimental garden project, the teachers learn about intercropping techniques, combining a cereal with a perennial plant such as *Atriplex halimus*. They could then replicate this technique in the garden with their pupils.

► Once trained, the team of teachers meets to decide what the scope of the garden project should be.

► Next, there is a meeting to bring together everyone involved in the project: pupils, teachers, environment professionals, scientists, and leaders of local NGOs. The pupils are told what activities the population is undertaking to protect the environment and maintain its ecosystems.

► Together, the group decides where the experimental garden should be located.

Its perimeter is determined so as to include perennial plants with important ecological functions (so that water and nutrient resources can be preserved) and, if possible, plants that humans and animals can eat.

It is not always easy to find a piece of land that is a habitat for many different species, but it is important for the carrying out of certain experiments that at least four or five perennial species are present.

Examples:
In the Sahel it would be useful to have a sample of four or five plants from the following species:
Balanites aegyptiaca, Maerua crassifolia, Panicum turgidum, Adansonia digitata, Boscia senegalensis, Acacia seyal, Acacia tortilis, Faidherbia albida, Andropogon gayanus, Ziziphus mauritiana, Ziziphus spina-christi, Vitellaria paradoxa, Tamarindus indica.
In Latin America, creosote bushes (*Larrea divaricata, Larrea tridentata*), Barbary fig (*Opuntia ficus-indica*), mesquites for their fruit (*Prosopis chilensis, Prosopis pubescens*), *Washingtonia filifera*, agave and yucca species.
It would also be an advantage for the experimental garden to have a source of water.

► After a detailed survey of the chosen site, the team of teachers, assisted by the project partners, explains to the pupils the main educational activities they plan to use the garden for:
• Study of the main native perennial species in the local environment;
• Practising methods of sowing, planting and transplanting;
• Making and maintaining a nursery;
• Soil fertilization;
• Associating native ligneous species with the cultivation of herbaceous plants, horticulture and annual crops;
• Maintaining a natural forest ecosystem and harvesting of products;
• Regenerating grassland;
• Wood production in a natural ecosystem;
• Protection of crops using various techniques: windbreaks, green belts, hedges, sun shelters;
• Introduction of rare and endemic plants in an appropriate biotope.

2. Prepare an inventory of noteworthy native species growing in a wider area beyond the garden itself

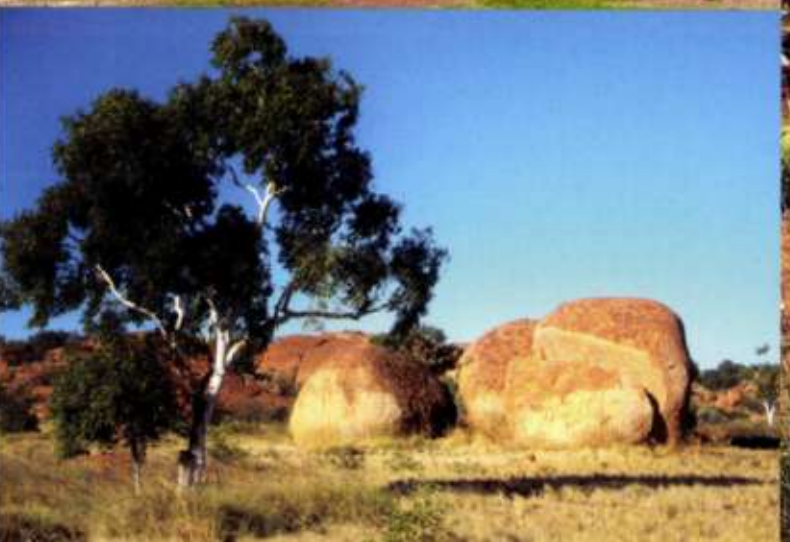
► With the teacher's help, the pupils make a detailed study of the main native species, both ligneous and herbaceous, as they grow naturally in their environment.
► They begin by considering the region's climatic and pedological characteristics:
• Is the region in an arid or very arid zone (less than 150 mm of precipitation a year)?
• Or in a semi-arid zone (between 300 and 600 mm, or more)?
• In the field, the pupils and teachers gather information about the nature of the **substratum** or **parent bedrock**.
• Is it limestone or siliceous? Is it sandstone in places? Salt rock?
• What is the texture of the soil, and of the eroding exposed rocks?
• Is the soil sandy, silty or clayey?
• Are there any **hamadas** (rocky desert)?
• Any **regs** (pebble desert)?
• Any **ergs** (sandy desert)?
• Are there any wadi beds, depressions where the soil is richer and where runoff collects after rainfall?
• Are there any expanses of clayey soil? Any zones in which the soil is rich in organic matter and humus (produced by the decomposition of animal-based and plant-based organic matter)?

► The pupils are familiar with the low precipitation and powerful heat that characterize dryland ecosystems.
In the area of land they are studying, they try to evaluate the plants' ability to tolerate water shortage and exposure to the sun, and to identify the resources and conditions present in the environments where they belong.
Are the sites surveyed heavily exposed to the sun, or comparatively shady? What is the maximum temperature? What kind of soil is there? Is there a recognizable biotope of some particular kind – a pond, or a wood? Is there an obvious watering hole, or any sign of undergroundwater?










► The pupils identify the different environments and then make an inventory of the corresponding species which benefit from the resources and conditions of each.

Examples:

In arid parts of the Sahel it is possible to observe species such as *Acacia tortilis* in very hot parts of pebbly regs. In depressions and wadi beds there are plants that have likewise adapted to the dry – or sometimes extremely dry – conditions, such as *Acacia laeta*, *Balanites aegyptiaca*, grasses such as *Panicum turgidum* (a wild cereal), *Acacia tortilis* and fruit species such as the *Boscia senegalensis* bush, which can bear fruit even on a very arid site. Wherever there is slightly more precipitation, *Balanites aegyptiaca* will grow on stabilized dunes because there is often groundwater which deep-rooted plants can reach underneath the dunes; *Panicum turgidum* and *Commiphora Africana* are also found here.

In areas with even more rainfall ('semi-arid zones'), a herbaceous covering of *Panicum laetum* will be found on clayey soils, along with a tree layer of *Ziziphus mauritiana*, *Acacia seyal* and *Faidherbia albida*, characteristic plants of the natural vegetation around ponds and streams.

The wooded savannah of semi-arid areas is dominated by a set of trees including *Combretum glutinosum* combined with *Acacia senegalensis* or *Acacia seyal* alongside baobab (*Adansonia digitata*), as well as a herbaceous layer of *Andropogon gayanus*.

3. List the ecological, dietary and revenue-generating functions of native species and plan how to grow them together

► Among the species listed, many of which will be perennials (flowering and bearing fruit year after year), the pupils distinguish:

- plants with important ecological functions within the ecosystem;
- edible plants that provide high-quality or even delicious food;
- plants that produce raw materials, or generate potential sources of revenue.

► Whatever the continent, pupils will find certain families, such as the *Leguminosae*, which fulfil essential functions in ecosystem development.

- In Africa, *Acacia tortilis* is an impressive water pump, bringing up water from deep underground; the species also helps to maintain phosphorus levels in the soil beneath its foliage.
- *Faidherbia albida* is a well-known nitrogen-fixing plant which fertilizes the soil by recycling nutrients through the decomposition of litter, and by bringing mineral nutrients up to the surface. Its phenology is inverted, so it provides vital shade and fodder during the dry season; and thanks to its powerful root system it draws water from the underground reservoirs without competing with other crops. *Faidherbia albida* also serves as an ideal perch for birds, and this makes a significant contribution to higher agricultural yields. It is the species of choice for agroforestry, and for any system combining trees with field or garden crops.
- *Acacia senegalensis* and *Balanites aegyptiaca* also raise the available nitrogen content in the soil where they grow; the roots of *Balanites aegyptiaca* help to purify polluted water and soil.
- The white thorn (*Acacia polyacantha*), by retaining the mineral elements of its leaves as soon as they are shed, promotes a high rate of recycling of these elements.

► The pupils list other plants that could be called 'ecological'.

For example, plants that help water conservation protect the environment as well. They manage this in various ways:

- They avoid the need for costly irrigation by developing a powerful root system that enables them to reach the water table or use moisture remaining in the soil after the rainy season.

94. From left to right and above to below: Species in their ecosystem: *Prosopis tamarugo* plantation and leaves (chile), *gramineae Pennisetum sp.* (Algeria), herbaceous savannah (Niger), baobab *Adansonia digitata* (Niger), *Ziziphus mauritiana* (Niger), eucalyptus and granite blocks (Australia), terrestrial bird's nest in the Australian *mallee*

Examples include legumes such as acacias.
• They survive on rainwater, storing it in their reserve organs and conserving it by regulating their **transpiration**.
Examples include cacti such as *Opuntia ficus-indica*.
• They vary their needs or co-exist with other species so far as water use is concerned.
This is the case with grasses in the dry wooded savannah that absorb huge quantities of water during the rainy season (producing biomass and maintaining other lower plants) which in turn transform into vestigial and dormant forms during the dry season thus ensuring water availability for trees.

► The pupils also list the plants of their region that help to stabilize the soil, such as the shea (*Vitellaria paradoxa*), whose complex root system prevents erosion in West Africa, or the Barbary fig (*Opuntia ficus-indica*) which is planted along contour lines to hold back the soil on the slopes of the Andes.

► After studying their region's 'ecological' species, the pupils turn to species which produce food and/or wood; some species, of course, will appear in both groups.
► They think of the best possible combinations of species (looking out for naturally-occurring combinations as well).
Which fertility-enhancing species would go well with a food-producing one to make a wild orchard?
Examples:
Acacia seyal and *Adansonia digitata*;
Faidherbia albida and *Ziziphus mauritiana*.

► Once this study phase is complete, the class is encouraged to think about some practical questions:
How to regenerate a population of plants with important ecological functions which is at present in decline or dying out? Which low-growing plants would it be useful to reintroduce around the base of the trees? What sorts of human activity should be promoted? What precautions need to be taken?

4. Return to studying the garden site

► Having recorded the beneficial plant associations to be found in the natural environment, the pupils examine the site of their garden, survey the plants growing there, and imagine the type of experiments they can carry out.

► Considering the edible species to be maintained, regenerated or introduced in the garden, the pupils focus on the project's experimental and creative aspect and give priority to one or more species that foster the links between:
• the natural ecosystem,
• health, nutrition, physical well-being,
• taste.
The enjoyment of flavour – the pleasure of tasting fruit and other food straight from the natural ecosystem – is an important aspect of the experimental garden.
► Fruit and vegetables will be grown in the garden.
After a while the garden will become a place for the direct tasting of various pleasant – and sometimes surprising – flavours from nature.
It is a place where the pupils will learn about and acquire a taste for neglected or forgotten flavours, and discover the subtleties of sweet, sugary, bittersweet, bitter, strong, hot, acidic tastes, etc.

97

95. *Biskra* dates, Algeria
©Olivier Brestin

96. Camels transporting dates, *Gabès*, Tunisia
©Michel Le Berre

97. Farmer collecting dates, *Timimoun* oasis, Algeria
©Olivier Brestin

98

100

98. Drying apricots, *Cappadocia* region, Turkey
©Michel Le Berre

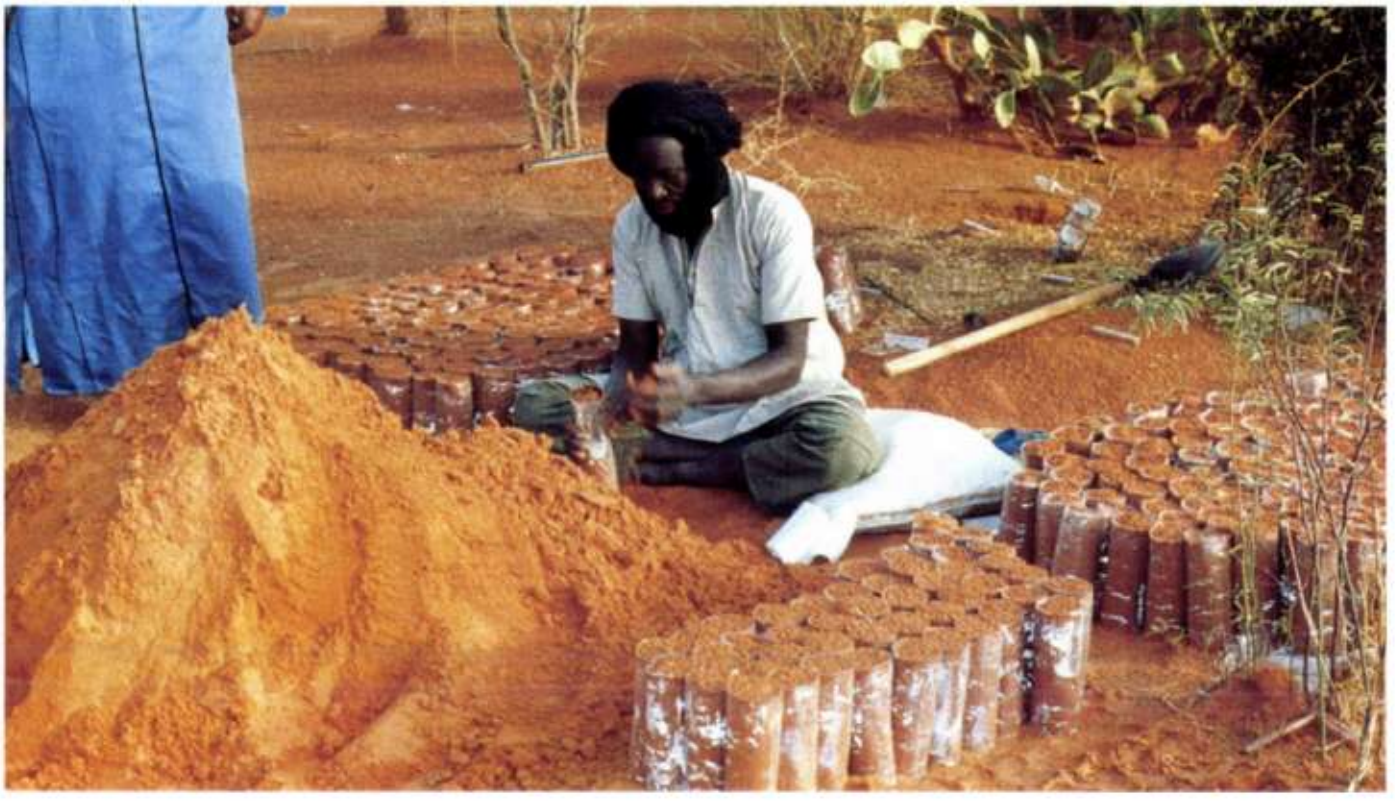
99. Watermelons in the market, Uzbekistan
©Michel Le Berre

100. From above to below:
Drying wheat, manioc, peppers, Benin
©Michel Le Berre

99

101

101. From above to below:
Orange trees bursting with fruit, Spain
limes and oranges, Mexico
©Olivier Brestin et Michel Le Berre



102. Plant production in a nursery, Sudan

► So this is an experimental centre, where pupils will examine the nutritional potential of edible perennial plants and also develop ways of preparing particular foods so as to appreciate their flavour to the full.
Depending on their region, they may be able to experiment with the following:
The leaves and fruit of *Maerua crassifolia*, the fruit of *Boscia senegalensis*, the delicious fruit of the various jujubes (*Ziziphus mauritiana*, *Ziziphus spina-christi*, *Ziziphus nummularia*), the flavoursome fruit, leaves and seeds of the baobab, vegetables gathered from species such as *Parkia biglobosa* in Africa, *Prosopis cineraria* or *Euphorbia caducifolia* in Rajasthan, *Prosopis pubescens* or *Tamarindus indica* in Central America, as well as fruit and palm hearts from semi-wild species such as the dwarf fan palm (*Chamaerops humilis*), the doum palm (*Hyphaene thebaica*) and the african fan palm (*Borassus aethiopium*).

5. Make a nursery and learn to sow seed and grow young plants

► At the start of the practical stage the pupils may decide to increase the number of fertility-enhancing plants in their garden - by planting new acacias, for example.
Note and suggestion:
It is advisable to sow seed in the nursery well before the young plants will be wanted for planting out.
In tropical countries the young plants will be transplanted at the start of the rainy season, to give them every chance of recovering and growing away before the dry season begins.

► The pupils collect ripe seeds from threshed acacia pods (or from the ripe fruit of any of the other species chosen) and plant them directly in earthenware pots around 10cm in diameter – or polyethylene bags approximately 40cm long, which are cheaper but can be a source of pollution.
► Before planting, the pupils fill the pots with a fertile mixture of sand and earth, as loose as possible. Earth consists of particles of eroded rock – clay, alluvium and sand – mixed with humus (decomposed organic matter).

They can improve the concentration of humus in the earth by making **compost** (see below).
► They put the pots on a flat piece of ground, protected from too much sun or wind.
When the first seedlings appear the weakest ones are removed, only the strongest in each pot are retained; any weeds are removed.
The pupils take turns to water the plants; this needs to be done regularly so that they develop plenty of roots as they grow to 30cm or 40cm high.

► As the seedlings grow, the whole class, pupils and teachers together, decides where they are to be planted out. This will depend on the preference of each species in terms of environmental resources and conditions.
The class then decides whether to add to the existing population of the species in the garden or introduce a new one (or both).

6. Fertilize the area to be planted and transfer the plants

► While they have been tending the nursery, the pupils have also been learning how to make compost, in order to enrich the soil where the saplings are going to be **transplanted**.
► For this, they dig a large hole, not too far from the school or the garden.
Into this hole they throw garden and kitchen waste: swept-up dead leaves, weeds, fruit and vegetable peelings; they add goat and dromedary droppings and cattle dung. They may also add straw from the harvest before covering it all with a layer of earth and leaving it for several weeks.
► The teachers show the pupils how to turn and water the compost regularly so that it all decomposes.
After a while it turns into excellent compost!

► As soon as it is decided where to plant a new tree or bush, the pupils clear the area and dig a fairly large hole (up to 50cm deep for a bush, or 80cm for a tree).
They leave the hole uncovered for a few days in order to aerate the underlying soil.
► With the teachers' help, they then enrich the soil that has been dug out. They remove stones and other debris and mix it in equal quantities with the compost that they have prepared. On the day of planting, they throw a small amount of this earth into the bottom of the hole, in the shape of a dome.
► They take the plant out of the pot by tapping all around it, moisten the root ball and gently untangle the roots; then they stand the plant upright in the middle of the hole, spreading the roots all around on the soil.
The teachers make sure that the top of the roots of the tree or bush is about 10cm below ground level.
► The class then fills in the hole, firming the soil with their hands or feet but not compacting it too much. Finally, a small well is made around the foot of the tree and filled with water (about 10 litres).

7. Strengthen the association between certain species and regenerate the natural forest ecosystem

► Having added to or extended the population of fertility-enhancing ligneous plants, the pupils and teachers can go on to the next stage: combining edible plants with the fertility-enhancing ones.
The relevant task at this stage is to regenerate a plant combination in which two species (one for fertility, one for food) already co-exist within the garden.

Several specimens of a selected food species are grown in the nursery and introduced as before. The idea is to reinforce the existing woodland ecosystem by introducing new fruit trees so that a wild orchard emerges over time.

► To avoid disturbing the biomass and the existing flora, the pupils could make an existing population denser without transplants from a nursery.
They may try direct sowing, introducing perennial plants by sowing their seed directly in the soil, without the nursery stage or the need for great amounts of precious water.
► The teacher explains:
Perennial plants that are direct-sown tend to produce an extensive root system fairly quickly, while the roots of nursery-grown plants very quickly become cramped in their container (pots or plastic bags). This means that plants sown directly, with their more extensive root systems, have a greater chance than nursery-grown ones of reaching the water that remains in the earth at the end of the rainy season. This makes them more drought-resistant.

► The pupils then select their seeds.
Example:
Viable seeds of the Baobab (*Adansonia digitata*) can be selected by means of a float test (empty seeds will float on water).
Before they are sown, they can be dropped into boiling water for five minutes, which helps to break their dormancy (a slowing of physiological functions when growing conditions are poor).

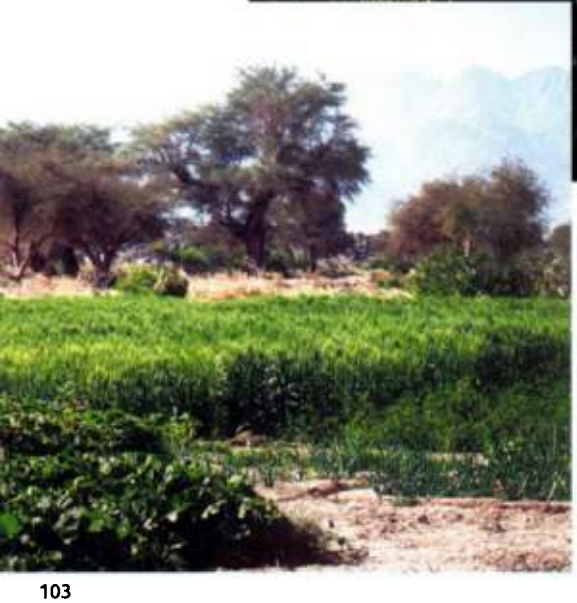
► Baobab seeds are planted once the rainy season is properly established. The seeds germinate after three weeks. If the seedlings are well cared for (provided with plenty of water until their root system reaches the water table) they will produce healthy, vigorous saplings – and in two years the trees can grow as high as two metres.
► The pupils plant baobabs leaving at least 20 metres between them, so that they have room to grow unhindered.
They also plant other ligneous species which provide food, and some grasses or low-growing plants at the base of the trunks (see next paragraph) to thicken the orchard's plant cover.

However, it will be several years (in the case of baobab, for instance) before the fruit can be picked - though leaves can be harvested sooner, subject to restrictions which the pupils learn to recognize:
• They must not disturb the canopy and the shaded environment it makes, which is vital for sexual reproduction during flowering and fruiting.
• They harvest the tree's products with restraint in a way that is fair to each 'gardener'and take smaller quantities from younger plants.
• They check the plant's maturity and its ability to bear high-quality, tasty produce which can be picked without damaging other parts of the plant vital for future growth.
• They observe 'off seasons' when there is no harvesting and the entire orchard is left untouched, to allow the plants a period of rest.

8. Regenerate crops and grasslands in the garden, and combine them with ligneous plants

► Outside the protected space of the orchard, the class experiments with combinations of ligneous plants and herbaceous species.

► First the pupils learn how to raise the density of a very sparse layer of grasses such as – in Africa – *Panicum turgidum*, *Andropogon gayanus*, *Aristida pungens* or indian sandbur (*Cenchrus biflorus*).
► The teachers tell them about perennial herbaceous plants which 'move around' year by year, shifting the point where they are rooted in the ground.
On site, the class observes how some herbaceous plants multiply locally by producing runners or **stolons**. These are a form of **propagation** in which stems droop to the ground and take root as soon as they touch it.



103

104

103. Market gardens and wheat fields, *Iférouane*, Niger

104. Banana and palm trees along the Nile, Egypt

In this way grasses manage to reproduce without seeds, in a process called **vegetative reproduction.**
A mother plant forms stolons which grow creeping along the ground and throw up shoots which, in time, become separate plants.
The pupils can get down and clear the base of a grass plant to see this for themselves.

► They carry out cuttings with various plants.
In Central and Latin America they can learn to grow new plants from the 'nopales'of various cacti, or large cuttings from stems comprising 4 or 5 of the readily detachable cladodes. These are harvested and dried for a few days (to prevent rotting), before being planted directly in the ground.

105. Various flowering blooms and fruit trees, *Lella Setti* plateau, *Tlemcen*, Algeria,

► For real regeneration of a sparse layer of grasses or prairie, the pupils sow seeds.
► They begin by finding seeds in ripe fruit or seed-heads picked from herbaceous vegetation: alfalfa, legumes or grasses. It is best if they work together, picking directly by hand.
► Then they thresh them, sort them (using sieves), and winnow them to expose them to the air, dry them out and make them firm. Finally they sow the seeds by scattering.
► They are careful to sow them near fertility-enhancing ligneous plants so that the seedlings can benefit from the organic fertilizer.
► Always seeking to combine wooded natural vegetation and low-growing plants, African pupils may include annual crops like pearl millet (*Pennisetum glaucum*), sorghum, or rarer cereal species from the wild that deserve to be rediscovered, such as *Panicum turgidum* (*afezu* in Tuareg) and three-awn grass (*Stipagrostis pungens*).
These wild cereals can be used like millet in uncooked preparations, and their seeds yield a 'wild flour' that the pupils can test and learn to prepare.
► The pupils also sow seeds from legume pods such as beans, and plant bulbils from edible bulbs such as onions.

Geophytes or bulb plants are of interest in dryland zones because, depending on the region, there is a considerable variety among wild species such as the *Iridaceae* of the Sahara, or small lilies. These plants grow from underground bulbs which produce smaller bulbs or 'bulbils', which can be separated and replanted.

► Lastly, in their horticultural experiments the pupils sow wildflower seeds taken from ripe capsules or seed-heads; these seeds will in turn produce beautiful flowering plants the next season.
► The pupils can make small flowerbeds, flower squares, carpets of wild, light inflorescences like lupins (*Lupinus tassilicus*) or other legumes, which may not flower for long, but will provide a real feast for the eyes for a short time!

9. Combine science and aesthetics in the garden

In considering where to grow their plants, which species to include, the size, shape and colour of their flowers, the suggested plant combinations, the variation of colour and size, and the arrangement of the various layers, the pupils will also be learning how to make and appreciate a more attractive environment.

► They draw sketches beforehand, imagining and predicting how the combination of colours, shapes and sizes will look – and then compare these with the results over time.
► In designing their plantations the pupils try, within the scientific and experimental framework of the garden, to find particular combinations of form and colour, though ultimately it will be nature that has the last word.
From an ecological point of view, what they are doing is a continuation of what nature does; and they observe how this works out over time.
The garden therefore combines an aesthetic aspect with the educational and scientific ones.

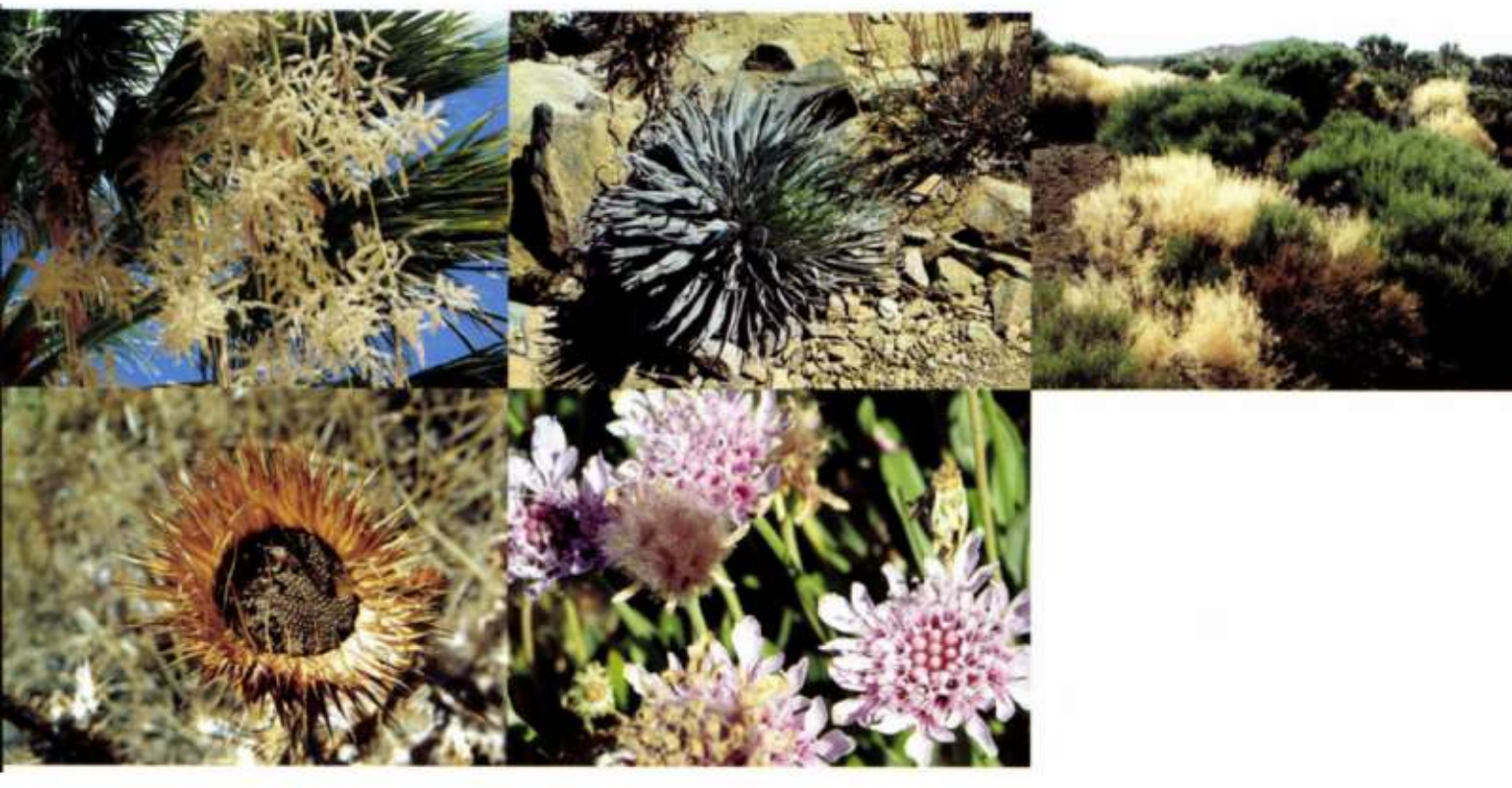
106. Prickly pear crops (*Opuntia ficus-indica*), *Atacama* desert, Chile
©UNESCO/Olivier Brestin

107. Crop fields, *Sidi-Bel-Abbès* region, Algeria
©UNESCO/Olivier Brestin

It is a space for experimentation in agroforestry: combining the cultivation of trees with that of herbaceous species so as to raise the biodiversity of agricultural ecosystems and preserve semi-natural and natural ones, improving their fertility while maintaining and enriching the soil.

► With the experience gained by working regularly in their own garden, the pupils can visit other sites where people make their living from work on the environment.
There they make use of their own experience, comparing practices and discovering techniques applied at a different scale.
This enables them to corroborate their experience, to go on learning and to join in discussions which will help to sharpen their critical faculties.
The teachers involved in the garden project (a true case of learning by doing) facilitate exchanges between the world of the experimenter and the world of the working environmentalist. They encourage visits and exchanges between the two sites.

108. Different species from the natural vegetation, *Tenerife, Canary Islands*



Chapter 3

Preserving Water Resources

01 Poem: Water, Source of Life

Level ★
easy

Place
classroom and outdoors

Duration
2 sessions

Objectives

1. Discovery of the environment

The pupils investigate, from documentary sources and their own experience, the extent to which water is a source of life in their culture and everyday environment, and report in writing, illustrating their findings by composing a piece of prose or a poem on various aspects of water as a vital resource.

2. Knowledge and comprehension

After this initial research the class will have a better understanding of water's main functions in the ecosystem, and will have made a firm connection between water use and the need for clean water.

Methodology

1. Examine water as a source of life in nature and the imagination

►Each pupil thinks about what 'water' means to him or her.
What images does it conjure up?
Quenching thirst? A spring, pond or well? The chore of water-carrying? River transport? Flood water, a wadi in spate or dry?
The pupils talk about their everyday experience of water, and in particular about hardships connected with lack of water, getting water and water management (rationing consumption among different needs).
►Then the teacher asks the pupils to recall a moment in their lives when they realized the extent to which water, with its refreshing or fertilizing powers, is a source of life.
Examples:

- Tasting fresh water from a spring;
- Discovering a shallow watering hole, hidden under the ground, when the cattle are thirsty;
- Gazing at the harvest after the land has been fertilized by rain;
- Finding a trickle of water hidden beneath a bed of dead leaves;
- Fishing in a well-stocked pond, or finding a marsh teeming with biodiversity.

►The teacher stresses the importance of water as a vital resource for all organisms.
Water is an element that flows through all living organisms.
It is essential to their growth and regulates their metabolism (the organism's cellular activity and its physiological and biochemical processes).
Examples:
Plant growth is dependent on water; a tomato is 95 % water.
A human being is 70 % water; so is human skin. The human brain is 75 % to 80 % water.

1. Oued *Ihérir, Tassili N'Ajjer*, Algeria
© Olivier Brestin

• A person can lose up to ten litres of water on a very hot day, through respiration, perspiration and excretion.
• This water must be replaced: a person can go nearly a month without food, but will not survive a week without drinking water.
• Animals likewise need water to regulate their bodies; so do plants, which transpire.

► Guided by their teacher, the class broadens the discussion and notes that water is a source of life in all its aspects:
• as a physical substance and object of scientific research;
• as a natural resource fulfilling important ecological functions within the ecosystem;
• as an element which has significance in our imagination, at the heart of many myths and symbols.

► The pupils begin their documentary research, focusing on these three aspects of water as a source of life. Each pupil keeps notes in an individual notebook provided for this activity.

► Under 'water, physical substance and object of scientific research', the pupils, assisted by the teacher, describe the role played by water in the origins of life on Earth.
Making notes and simple drawings based on scientific images (microscope images) researched by the teacher, the pupils summarize the story of evolution from the first appearance – in water – of protozoa, bacteria and algae, several billion years ago. It is from these unicellular (single-cell) micro-organisms, invisible to the naked eye, that multicellular organisms such as human beings have evolved.

Following this initial research, the class has a choice.

2

3

4

5

6

2. Ducks drinking from *Rio Vilama*, Chile
© UNESCO/Olivier Brestin

3. Seagulls perched on water pipes, *Huasco* region, Chile
© UNESCO/Olivier Brestin

4. Waterfall, Oued *Ihérir*, *Tassili N'Ajjer*, Algeria
© Olivier Brestin

5. Horse, *El-Kala* National Park, Algeria
© Olivier Brestin

6. Young *Tarahumara* girl quenching her thirst, Mexico
© UNESCO/Olivier Brestin

►Some of the pupils establish a link with water and the imagination, through myths and stories about the creation of the world and the beginning of life.
Water is mentioned in many cosmogonies, and the pupils give short accounts in their notebooks, quoting and describing these.
Examples:
In the *Sura Al Baqara* (verse 164), of the Koran, water is associated with the creation of the world by Allah: "In the creation of the heavens and the earth; in the alternation of night and day; in the ships that sail the ocean with cargoes beneficial to man; in the water which God sends down from the sky and with which He revives the earth after its death, dispersing over it all manner of beasts; in the disposal of the winds, and in the clouds that are driven between sky and earth: surely in these there are signs for rational men". [Version of N.J. Dawood, Penguin, London 1999]
In Hindu cosmogony the creative cycle contains frequent references to water through the aquatic plants that grow in muddy waters: as Vishnu sleeps floating on the water, a lotus grows out of his navel, and Brahma appears on it.

►Another group of pupils links water as the source of life to water as a natural resource and a unique habitat in arid and semi-arid ecosystems.
One example that could be suggested is that of a grassy marsh:
As a biotope of micro-organisms, flora and fauna, a space covered with herbaceous aquatic plants such as bulrushes or cattails, a genetic reservoir, a breeding-place for birds, fish and insects, the marsh teems with life.
The pupils gather information about this precious biotope, making detailed notes and drawings.

►A third group explores the idea of water as associated with the origins of human life: the amniotic fluid or water within the womb, and – by extension – milk, lacteal liquid, water that nourishes.
►The pupils sketch or briefly describe the rituals – in their own or another culture – in which the amniotic fluid is regarded as sacred and plays a part in the welcoming of new-born babies.
Example:
Among the Bambara in Guinea it is customary to get babies to drink water from their first bath before anything else. While still covered in its birth fluids, the child tastes this first bath and in this way becomes aware of its individuality by 'tasting itself'.
►Others look at the cultural ways in which water and milk are associated:
Many Vedic hymns refer to our mothers' waters as giving us 'milk'.
Water and milk are part of the basic diet of nomadic herders, who often associate them in their proverbs.
The pupils carefully note down and remember these sayings.
Example:
"If the water in your flask is sour, it is because you put curdled milk in it."

►It is useful if the pupils, whatever part of the world they live in, can draw on their own particular culture for references to water as a source of nourishment.
The water of ponds or seas is often described or referred to as being nourishing, fertile, full of fish: a 'living pond', a 'sea of nourishment', the sea as a 'mucus' rich with microscopic organisms.
►Pupils in different regions could compare notes and share the results of their research, for instance by photocopying their class notebooks if the means are available, and sending them to another school belonging to the network of **UNESCO's Associated Schools Project Network** (ASPnet). In this way they can discover obvious parallels in different arid regions.

7. Valley of crops, Morocco

2. Note some essential aspects of water as a vital resource

► The teacher summarizes the main functions of water.

• It is a 'biotope', a natural habitat and a reservoir of biodiversity.

• It performs functions which are directly useful to humans, as an essential component underlying the production of food and energy.

• It has a regulatory function within the environment, at more than one level:

– Water governs climate (see Chapt. 3, act. 3, p. 154);

– It governs soil formation:

The thin layer of water which holds together the crumbled fragments of eroded rock to make soil is, like the air that fills the gaps, an essential component of every soil on Earth.

– It governs agricultural practices:

Rain that wets the ground gives rise to the harvest, it is essential for germination and (along with nutrients) for plant growth.

Water governs agricultural activities by keeping crops alive – where necessary through irrigation, if there is insufficient rain – and by washing the soil (for water is the main cleaning agent), which facilitates crop rotation.

3. Focus on water as a source of fertility or nourishment in pupils' everyday experience

► Next the pupils return to the theme of water as a source of fertility or nourishment.

They develop this theme by linking it to bodies of water that they know and visit regularly in their local environment.

- In what ways are these water bodies, which provide access to fresh water reserves either above or below ground, sources of life for local people?
- Are they perhaps the reason why the village was established, why the community formed in the first place?
- How do they contribute to human activity?
- Is water used for crop irrigation?
- Is there a system – man-made or natural – for decontaminating or purifying the water so that it stays clean and fertile?
- Once a wadi has dried out at the end of the rainy season, is it rich in fertile alluvium?
- Is there a traditional or age-old system for collecting groundwater, such as the Algerian **foggara** (also known as *khettara* in Morocco, and *quanat* in Syria and Iran)?
- Has this system been recognized and perpetuated by today's community as being particularly suited to the characteristics of water in dryland areas?
- Does it still ensure balanced, sustainable use of high quality (clean) water in the village?

► The pupils gather information in their notebooks, based on the knowledge and stories of people directly involved with water (farmers, herders, vegetable growers, mothers and housewives, water authorities).

► They note the words (local terms and technical vocabulary), actions and occurrences, circumstances and colours that tell the story of the water bodies in question. They list the various names by which these are known in their language.

Example:

In the Sahara, the class learns definitions for *wadis*, temporary streams that flow in times of rain but remain dry for long periods; **gueltas**, more lasting pools, usually with no visible flow (natural cisterns in the rocks, for example); **sebkhas**, or temporary salt marshes; and the freshwater pond in all its aspects, whether full,

8 and **9.** Balance-beam well, *Béni-Abbès, Algeria*
© Michel Le Berre

8 9

drying out, or filling up; also (in some cases) riverbanks, lakes and marshes.
They compile a list of the Arabic and Tuareg names given to wells, depending on their characteristics:
- The *chadouf*, or bascule well;
- The *gherghâz*, or animal-powered well;
- The *hatâta*, a temporary well where water appears in the sand as soon as one starts digging by hand;
- The *anoû*, a deep permanent well; if a pulley is attached the name changes to the feminine 'tânout'.

► For each term, the pupils give an example from their local environment.
► In some cases, they give the official or unofficial name of the place where the watering hole is located, which sometimes includes a reference to water.
They describe its surroundings and situation, its sights and sounds, and the plants, animals and objects to be found there.
► In each case the pupils' description includes people and describes the human activities at and around the watering place, bringing out its importance in the life of the population.
Example:
The river: boarding a pinasse or canoe, the effort of punting and steering a boat using a single pole, the feel of picking up speed and slicing through the water, the silhouettes of African fan palms on the riverbank, the graceful, regular flight of the pied kingfisher as it suddenly dives out of the African sky, the fisherman's gesture as he casts or hauls in his net, the harvesting of millet on the riverbank.

10. The little egret (*Egretta garzetta*), Lake *Tonga*, Algeria

11. Fishing with a net,
Lake *Nokoué*, *Ganvié*, Benin

►The teacher explains water as a bringer of fertility, a function intrinsically linked to its cleanness:
• Irrigated agriculture and animal husbandry, the main economic activities in dryland areas, use enormous quantities of available water for producing food: fruit, cereals, other food crops, vegetables for human or animal consumption, and meat.
• The production of plant-based foods requires the use of clean, sanitary water, from irrigating the land to washing the produce: the use of poor irrigation water leads to the salinization of soils already saturated with pesticides and fertilizers, and produces foodstuffs contaminated with harmful substances (heavy metals, nitrates) and pathogenic organisms. These foods are then liable to contaminate people's bodies.
• Furthermore, poor irrigation water, or pesticide and fertilizer present in the soil in excessive quantities, also seeps down and pollutes groundwater reservoirs.
This sets up a vicious circle of pollution.

• The teacher stresses that water can only be a source of life if it is clean, clear, and pure.
Water taken from nature and used must itself be 'cleansed' before it is returned to nature.

4. Conclude documentary research with the notion of water as purifier

One of the primary functions of water is to remove dirt.
In most cultures this cleansing function is linked to the idea of 'purification'; water is thought to eliminate not only outward marks, but inner blemishes as well.
This is often described and experienced as a life change, a rebirth.
The pupils research examples of cultural practice around the world based on the idea of purification by water.

Examples:

- Baptism in holy water, for Christians;
- Ablution before prayer, for Muslims;
- Initiation rituals in African societies that involve water and are meant to purify and protect the initiates:

– At the end of their initiation, for example, Bambara neophytes are sprayed with water from the mouth of the chief of the circle of initiates. They are then washed twice: first by a venerable initiate with water drawn from the village's sacred pond; and then at its sacred well.
– In Africa, throwing water is a common ritual, designed to chase away evil forces and to purify individuals.

► The class thinks about the images of water symbolizing purity in its own culture:

- Does the source of a spring evoke the image of purity?
- The sacred water of the village pond?
- A few drops sprinkled with an olive branch, a sprig of hyssop or a sacred plant?
- The morning dew?
- The water drawn from deep underground by the *foggara*, flowing through ancient galleries carefully lined with a mixture of clay and straw?

► The pupils add quotations from the best-known sayings related to the theme of pure water.

Example:

"A jug of pure water cannot resist a spoonful of dirty water."
African proverb.

5. Write a poem about water as a source of life

► Drawing on these exercises, which contain a rich variety of words, expressions and images, each pupil chooses his or her favourite ideas and writes a poem or a poetic piece of prose on the subject of water as a source of life.

► These compositions are then illustrated and shown together on a large display.

12. Young woman washing her hair in a river, Ecuador

02 Paint, Liquidity, Transparency: Water and the Senses

Level
easy

Place
classroom and outdoors

Duration
3 sessions

Objectives

1. Discovery of the environment

By using and working with watercolours, pupils try out and really appreciate water's physical qualities such as liquidity and transparency, and thus improve their understanding of its appearance and colour, and of its effect on the environment – particularly in terms of erosion.

2. Knowledge and comprehension

By studying water in the landscape, the pupils start to learn about natural resources – water lying above or below ground – in the context of the water cycle both in time and space.

Methodology

1. Use paint to highlight the physical qualities of water

Water awakens or 'revives' all of our senses.

► In the classroom, the pupils discuss their experiences of the sensory characteristics of water. They think of special moments of contact with water, and describe what they felt like.

Examples:

- Quenching their thirst with fresh water from a spring;
- Diving into a clear *guelta*;
- Listening to the sounds of undergroundwater springing up or gushing forth;
- If the sea is nearby, listening to the backwash when the tide is high;
- Floating on the surface of the water;
- Watching clouds;
- Watching the flow of a river;
- The smell of the catch from a fish-pond;
- Feeling the evening damp come over a marsh;
- Tasting the juices in most foods – which is their hidden water content.

Perceptions of water – or of the longing it creates in us – are part of each person's unfolding awareness of their environment, especially in dryland regions where the need to drink and be refreshed is felt regularly and where water is a precious commodity – a sacred one, even.
"Aman, Iman" ("Water is life"), the Tuaregs say as they quench their thirst from their traditional gourd or drink tea, three small glassfuls, three times over.

► The teacher gets the pupils to use watercolours to reveal water's physical tactile and visual qualities such as liquidity and transparency.

13. Young boy watching a pirogue made from papyrus leave the shore, Ethiopia

► They paint with various tools: a paintbrush or similar object, a sponge, a stick, a finger or hand. They paint on different materials such as cardboard, thin paper, recycled paper or fabric stretched across a frame.
► By using particular painting techniques such as running, dragging, sprinkling and dripping, and observing the effect of each on their tool and on the paint (which will sometimes be thick, sometimes dilute), the pupils recreate water's dynamic processes and make them visible, like the traces left by water itself in the natural environment.
► They observe very closely as they test out the liquidity and fluidity of their materials; and as they do so they discover the natural effects of absorption, covering, flooding and sprinkling that are created by water and the way it behaves – and that humans use in the ecosystem (through irrigation, for example).

► First of all, the pupils work in groups to create plain single-coloured surfaces by laying on several coats of paint.
They repeat the process, using more water each time: the same paint, but more and more diluted.
► Then they can make marks on a dense, uniform surface with a paintbrush full of water: a streak, or the trace of a flowing movement full of curves and curls.

They observe the results: water dilutes paint, lightens it, or moves it around; they notice how flowing and dynamic – sometimes how natural and beautiful – it makes each brushstroke.

► Still under the teacher's guidance, they introduce different colours: still blocks of colour at first, placed side by side (without waiting for them to dry), then marks left by moving paintbrush dipped in more than one colour, and then using more than one paintbrush. They observe the way paint runs, and the overlapping effects this produces.
Then they experiment with sprinkling the paint or flicking it; and more controlled dripping effects.
► Then the teacher suggests a further exercise:
A pupil lets a drop of paint fall onto a piece of paper and then tilts and moves the paper around this way and that, to create a pattern determined solely by the movement of the paper until all the liquid has been absorbed.
Other pupils watch the effects of the absorption and combination of different coloured drops, and use the same method to produce their own paintings.
The resulting paintings can, once dry, be touched up with a pen or paintbrush, to introduce figurative elements or contrasting material.
► Finally, the class studies the relationship between water and oil, by using the following technique to reveal the patterns formed by dropping oil-based paint onto the water's surface:
• A large container – a basin or dish – is filled with water.
• A group of pupils lets a few drops of oil paint, of various colours, fall onto the surface of the water. (Only small amounts of such paint are used, to avoid polluting the environment later).
• Using a stick or any bit of wood, other pupils stir this floating mixture – and shapes begin to emerge.
• When an interesting shape appears, the pupils capture it by placing a sheet of paper on the surface of the water.
• They carefully remove the sheet, on which the floating shapes and colours have been printed by absorption.
This exercise can be varied by masking part of the sheet with a stencil (stuck on with glue, for example).
The hidden part conceals a drawn motif that is not exposed to the floating colours, whose captured shapes serve as a background framing the motif when the stencil is removed: they could for instance represent waves, a river, the ocean...
A comb can also be used to make different patterns on the surface of the water.

► Once they have grasped all of these expressive techniques derived from paint and its liquid, watery characteristics, the pupils exhibit their pictures on the wall. All together, they illustrate various versions of an approach to water that is both sensory and sensitive: its elusive liquidity, its ability to intermingle, infiltrate, overflow and cover up.

2. Learn to read the traces of water erosion in the landscape

► The teacher takes the pupils outdoors where, sensitized by these exercises, they are readier to notice and understand the traces left by water, and its action on the landscape and the environment.
• They identify the traces of **runoff**: the signs of water moving down slopes and hillsides.
Examples:
The pupils observe the channels formed by the flow of runoff and the snake-like lines, bypassing pockets of vegetation, which can form a kind of chequered pattern in the landscape.

14. From left to right and above to below: River erosion (Niger), flow on granite arena (Zimbabwe), dried up *Ihérir* wadi (Algeria), African Palmyra palm trees along the Niger River, temporary pond (Algeria), dried up *Ghéris* wadi in *Errachidia* region (Morocco), torrent drying up and serious hydric erosion (Mexico)









15

16

15. Artesian well, *Errachidia* region, Morocco

16. River current transporting sediment

• The pupils also identify the traces of **infiltration** through natural cracks in rocks and in soil.
• They observe the beds of the wadis, which can be quite wide where the land is flat.
• If they are near a river, they observe the signs of **fluvial erosion** by identifying, where possible, slopes that have been carved into steep banks marking the edge of the floodplain, and the banks of the permanent riverbed, also heavily eroded.
Everywhere water goes it cuts channels, in which it flows – and from which it sometimes overflows.

► The teacher stimulates the pupils' imagination by quoting texts evoking the power of water, among other elements.

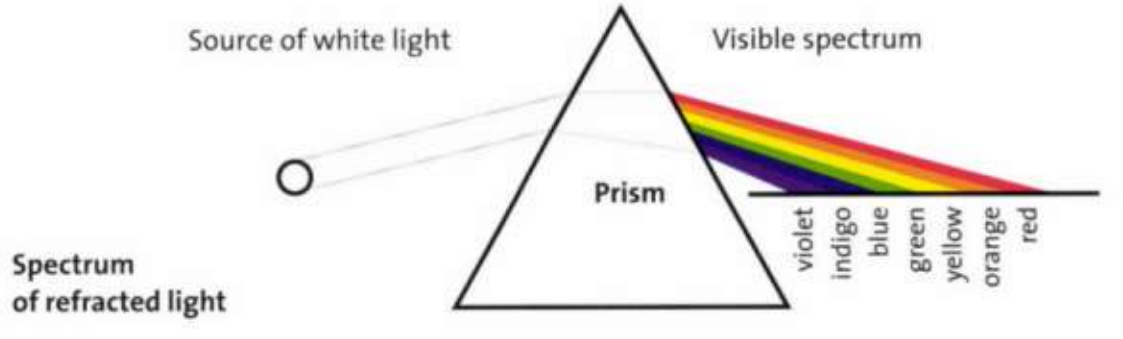
Examples:
What is more fluid, more yielding than water?
Yet back it comes again, wearing down the rigid
strength which cannot yield to withstand it.
So it is that the strong are overcome by the weak,
the haughty by the humble.
This we know, but never learn.
Lao Tzu, Chinese philosopher, 570 Br/ tr. Witter Bynner

3. Focus on the colour of surface water

Another characteristic of water highlighted by the use of paint is its transparency which, as the classroom exercise showed, is relative to the dilution of the matter (i.e. the paint).
• Is water transparent in the natural environment?

• Not all water is as clear as a gushing spring.
► Taking samples from several different water sources, the teacher shows the class that water which seems coloured or full of particles may be more transparent than it looks.
► The teacher goes on to explain:
• In a natural, unpolluted environment, water may be clean even when it does not look colourless to the eye.
• Nevertheless, once water has been drawn for use it should be clear; if not, it needs to be purified, filtered and decontaminated before it is drunk or used to make paper, textiles or food products.
► The class then studies the colour of water.
Taking the pupils outside, the teacher invites them to consider how they perceive water when they are close to the watering holes or bodies of water they find in the surroundings.

► First the teacher explains the relationship between sunlight and the colour of water.
• When the sunlight penetrates fine water droplets, the colours of the rainbow appear.
► The teacher explains:
• In the case of visible light we know that the **refractive index** of water or any aqueous environment is, like that of translucent glass, different from that of air.
• As a result, each of the wavelengths that together make up white light (and are not normally visible as individual colours) is diffracted to a different extent when it passes from air into water or back – so its separate colour becomes visible to the human eye. That is how the rainbow appears.



► The pupils use notes and sketches to record the colour of the water at the various sites they visit.
► The teacher continues:
• The colour of the water is due to the organic and mineral substances it contains.
• These different compounds absorb different frequencies of light. The overall colour of a body of water is accordingly the product of our perception of a whole set of coloured compounds that are either dissolved in the water or lying on the bottom.
Examples:
Water may look red because of decomposed minerals such as iron.
Green may be due to organic material such as algae; the presence of plant decomposition products, on the other hand – humic matter or tannins – may turn such greens to yellow or brown.

► The pupils think about the transparency of water in their dryland regions, where springs are often dry and surface water may not last long.
The pupils note the different-coloured waters of ponds, gueltas, pools of brackish water and terminal marshes.
They take samples at these sites.
► They understand that these waters 'carry' with them the colours of the environments through which they have passed or where they stand.

17. Bathing near the *Tifounassine* dam, *Goulmina, Errachidia*, Morocco

The colour of the water is determined by the composition of the rocks that it has bathed (water upwelling in gueltas), the sediments it has carried (water flowing in pools or wadis) or the vegetation it has dragged along or decomposed (water from marshes, rivers, ponds and lagoons). It also reflects the characteristics of its present surroundings (algae and aquatic plants in the water, and the nature of the sediments at the bottom).
The colour of water therefore tells a story, both past and present.

► The pupils sketch these bodies of water in different weather conditions and at different times of day.
At the same location, changes in the intensity of light alter the colour of the water.
► They also produce sketches from different angles: looking straight down, close-up or from a distance. Here too, the colour of the water varies.
► At close range, they capture the detail of the expanse of water, which is not all the same colour; using coloured pencils they try to capture the play of reflections and their coloured shadows on the surface.

4. Taste drinking water and understand its origins

► To conclude this activity and to reinforce the ideas that water has a history and its passage is a matter of time, the class visits various points of access to drinkable water: the village well, a water fountain, a natural spring emerging or gushing from the ground.
► The pupils taste various samples of water fit for drinking.
Although it is often odourless, it has a taste; and this taste likewise reflects the characteristics of the environments through which it has passed.
► Since it is not always easy to describe these tastes, the teacher asks the village water diviner to help.

By examining the shape of the land, the water diviner can often locate the presence of an **aquifer** if it is not far below ground level.

► The diviner describes the path taken by the water since it flowed down the hillside, percolating through natural cracks in the rock and slowly making its way through different soils.

► The diviner, who is often a 'water taster', can help the pupils to describe the taste of the water they sample. Depending on the various soils, rocks or vegetation they have passed through, these samples may taste of sulphur, iron or iodine, sometimes with a plant-like aftertaste.

It takes training to be able to recognize the more subtle differences: expert water tasters talk of camphor, cucumber, onion, and many other tastes.

► Continuing the study of drinking water and its travels, the teacher establishes the relationship between the water that we drink and the groundwater drawn from a well or spring. The very best for drinking is water filtered naturally as it passes through soil and rock, whether it is pumped up from the groundwater reservoirs or taken from a spring that emerges and bubbles up from the ground.

► The teacher also points out another relationship: that between the drinking water drawn from underground and the surface water that seeps down into the ground. It is the same water: it starts as surface water from precipitation, it then percolates underground, and eventually some of it rises to the surface again by various means:

- The aquifer meets the surface at some point, so that water seeps through and springs emerge in various places;
- People dig or bore directly down into the water table to satisfy their constant demand for water, for drinking and irrigation;
- Plants absorb water through their roots and transpire it through their leaves.

This final point opens up the idea of the water cycle, which is the theme of the next activity.

18. Young child washing his hands, *Tienfala* village, Mali

19. Tuareg pouring tea, *Tassili N'Ajjer*, Algeria

18

19

03 The Water Cycle

Level ★ easy

Place classroom

Duration 2 sessions

Objectives

1. Discovery of the environment

The pupils concentrate on the different states of water as a substance; guided by the teacher, they begin to understand where these transient states fit into the various stages of the water cycle.

2. Knowledge and comprehension

Through a series of 'sound plays' which they learn to perform using mime and sound effects, the pupils learn about the water cycle and its impact on the environment.

Methodology

1. Consider water's different states and the origin of water resources

►The teacher teaches the class to distinguish the three states of water: liquid, solid and gaseous. The teacher may conduct some simple experiments on the subject.

►The pupils heat water and observe **evaporation**; water vapour marks the transition from the liquid to the gaseous state.

A refrigerator – not always available in rural dryland regions – is needed in order to observe the transformation from liquid to solid. If they can use one, though, the class makes some ice, and then lets a big ice cube melt in the sun.

A cold pane of glass can be placed above a container of boiling water, to demonstrate the state change from gas to liquid as the water vapour immediately condenses onto it.

►The teacher may also encourage the pupils to prepare a list of nouns associated with the adjectives 'liquid', 'solid' and 'gaseous'.

Examples:

Associated with the liquid phase: spring, rain, guelta, terminal mere, river, pond, marsh, sea and ocean.

With the gaseous phase: vapour, fog, steam and mist (not strictly accurate, since mist and fog are actually liquid forms of water, formed by the condensation of water vapour which itself is invisible to the naked eye).

With the solid phase: ice cube, ice, snow, snowflake, glacier, iceberg, ice field and igloo.

►Each pupil sums up in a single line the connotations of each of water's states for him or her, in its different forms.

What do 'the sea', or 'ice' or 'an iceberg' mean to a child from the Sahel or the steppes of Mongolia?

►The teacher uses pictures in documentation already available or researched in advance, to illustrate, describe and comment on the different states in which water can be found.

►The teacher provides some facts that are prerequisites for a proper understanding of the series of transitions that water goes through in the course of the water cycle:

20. *Aletsch* glacier, Switzerland
© András Szöllösi-Nagy

21. Torrent, Chile
© UNESCO/Olivier Brestin

• Fresh water is a rare commodity; 70% of the Earth's surface is covered in water, 97.5% of which is salt water (the seas and oceans);
• Less than 3% of the water is fresh water and most of this is inaccessible, either frozen in the icecaps or in deep groundwater reservoirs. A total of barely 1% of the Earth's water is easily accessible fresh water in rivers, lakes, ponds and groundwater that is tapped by digging wells;
• These resources are limited, even though they are often replenished because water is constantly on the move, circulating through ocean, atmosphere and land in a complex cycle driven by the sun. Nevertheless, the teacher stresses the importance of non-renewable undergroundwater in arid regions: these are fossil water tables, non-renewable either because they are enclosed in geological pockets or because any water inflows are either too short-lived or too infrequent.

2. Break down the stages of the water cycle for easier comprehension

► At this stage the teacher draws or copies a diagram of the water cycle onto the blackboard. Then the teacher explains the main stages of the cycle:
• Driven by the energy of the sun, water in the seas and oceans evaporates into the atmosphere in the form of water vapour.

The same process takes place at the surface of lakes, glaciers, and land (evaporation), as well as on animals' skin and plants' leaves (transpiration). The word for the phenomenon as a whole is **'evapotranspiration'**.

• In the atmosphere this invisible vapour condenses into tiny water droplets, which form clouds. These are blown by the wind from the sea towards the land.

• As they rise to the mountain summits, they cool; the tiny water droplets collide and coalesce to form bigger drops which are heavy enough to fall as rain.

• So the water vapour of the clouds returns to the surface as rain or some other form of precipitation; seven-ninths of rainwater falls into the sea, and two-ninths onto land. It evaporates again, and the cycle continues.

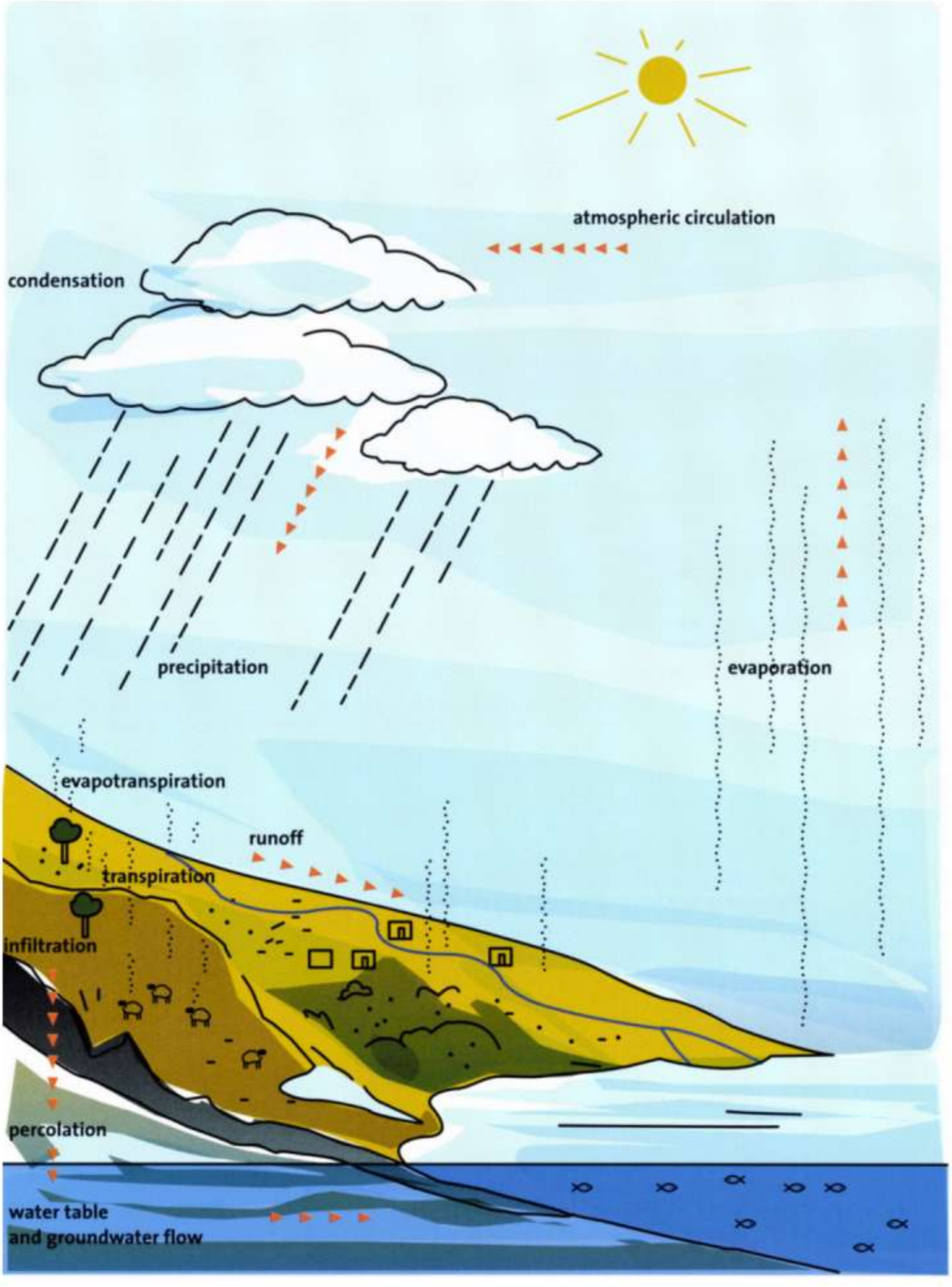
• Some of the water that falls to the ground, however, seeps into the soil and reaches the water table. Some is used by living organisms in various ways: percolating water may be absorbed by plant roots, while water in the atmosphere may be absorbed directly on contact with leaves, stems or skin. This applies to all living organisms.

• When more rainwater falls on the land than can seep immediately into the ground or be taken up by organisms, the excess runs off into lakes and rivers, and so back to the sea. Sometimes, though, this runoff flows into rivulets that never reach the sea, but flow into temporary wadis or gather in hollows forming temporary lakes or ponds.

• To summarize: in the water cycle, most evaporated water returns quickly to the sea; just a small proportion passes through living species (including humans), and enables cells, organisms and ecosystems to function. Here the teacher reminds the class that water accounts for over 80% of the total body mass of plants and animals together.

► After explaining the various stages of the water cycle, the teacher makes a number of important points:
• Plants have an influence on the water cycle which must be taken into account:
– Water evaporates after falling on plants as rain or forming as dew.
– Water absorbed by roots and transpired by leaves also evaporates.
– Plant roots promote water seepage and retention within the soil, which they help to stabilize.
– Some water is also retained in the plants themselves.
Consequently, when a region is severely deforested there is a heavy impact on the water cycle and especially its runoff and infiltration processes; this often leads to erosion and flooding as soon as there is a heavy downpour.
• The more slowly the water circulates, the more it interacts chemically with the environment. The faster the process, on the other hand – especially given the concentrated precipitation of dryland regions – the more pronounced the effects of erosion: runoff is aggravated because the water finds little or no plant cover to stop it. Another reason why the process goes so fast is that evaporation is immediate since temperatures are high and the air is very dry.

The water cycle



22. Clouds over *Ayers Rock (Uluru)*, Northern Territories, Australia

23. Car crossing *Shirnside Creek* following the rains, Northern Territories, Australia

3. Understand and interpret the water cycle through a series of sound plays

► At this stage in the presentation of the water cycle, the teacher introduces role play to associate the various stages of the cycle with sounds imitating those made by water in its various transient states. This series of 'sound plays' helps the pupils to recognize the stages of the water cycle and fit them into a clear pattern.

► The teacher begins by asking the pupils – in groups – to write down their version of the sounds water can make in its various states, or in different climatic or atmospheric conditions.

Examples:

- the din of a storm;
- the rumbling of thunder;
- the hammering of rain on the roof of a house;
- the drumming of rain on a tent;
- the steady dripping of water from a roof after a storm;
- the intense flow of runoff: noisy nearby, or more muffled in the distance;
- the gushing of a torrent;
- the powerful flow of a roaring river;
- the babbling of a spring on pebbles;
- the 'glug-glug' of water as a jar is emptied.

► The pupils may also imagine sounds that they will obviously never have heard, such as the crack of thawing ice on a pond or the muffled sound of footsteps sinking into the snow.

► They then try to recreate in wordless mime – physically, using their bodies – the sounds, expressions and behaviour of living organisms under certain water-related conditions of climate or weather.

Example:

The atmosphere before a storm: the torpor that grips the population, the humming of insects, evaporation at its peak, the cries of a flock of birds, their agitated flight skimming the ground, the irregular beating of their wings, followed by the rumbling of thunder and the pouring rain; the way many mammals keep still in the rain or refresh themselves, splashing around, drinking it in, and so on.

24. Group of villagers and experts in front of Nile waterfalls, Ethiopia

25. Young women carrying water jugs, Guatemala

►After preparing and perfecting a number of such playlets, the pupils together 'act out' the different stages of the water cycle.
►They make noises and imitate expressions using gesture, movement and all kinds of props and sound effects.
►They use various musical instruments, wooden objects that make cracking or creaking noises, iron objects that can be struck or rung, stones and gravel shaken in various containers and, of course, water (in moderation) that can be manipulated, sprinkled, poured gently or dripped.
►The teacher suggests breaking down the stages of the cycle into several sound plays assigned to several groups. So there might be, first, the atmospheric heaviness before a storm, the downpour itself, the runoff and rushing water, infiltration and absorption, **percolation**, and the return to the sea.
►Each group combines sound effects with interpretation as they stage their play.

Examples:

The behaviour of insects before a storm could be represented by throat noises and furtive movements;
A long, heavy downpour may be simulated by rapid dripping into several buckets or tubs, sustained drumming on the stretched skin of a djembe drum, gravel and sand shaken around in bowls – or one pupil could mime an elephant hosing itself down generously with its trunk.
Percolation, on the other hand, could be simulated by a very slow drip and an extremely faint sound of water on the surface of a bucket.

►Once the groups have learnt their routines and how the different playlets fit together (different arrangements are possible), the 'show' could be performed in front of the whole community – and certainly should.
The show could be called: "Listening to the water cycle", for example.

04 Diary of a Watering Place

Level ★★ intermediate

Place classroom and outdoors

Duration 4 sessions

Objectives

1. Discovery of the environment

By keeping a diary in which they record all their discoveries, the pupils learn about the main aspects of surface water sites in dryland regions – fascinating places, often ponds or lakes, and always teeming with life.

2. Knowledge and comprehension

As the diary fills up with sketches, drawings, notes and entries, the pupils gain a deeper and deeper understanding of the watering place as an indivisible whole that performs basic ecological, cultural and directly practical functions for local people within the ecosystem.

Methodology

1. Choose a watering place in the countryside and start a diary for it

► The teacher suggests a particular watering place in the neighbourhood for the class to concentrate on.

Preferably this will be a natural site of surface water, such as a temporary pond in Africa, a **guelta** in the Arab world or Australia, or an intermittent stream in Central America; the object is to study its ecological role in the ecosystem.

Once they have chosen a watering place, the pupils put it in context.

► For this each pupil gets a medium-sized notebook which he or she will use throughout this activity for recording notes, interviews, impressions, finds, drawings, collages and rubbings that convey information about the watering place: all the discoveries made there and all the information that can be found out.

► The pupils discuss with their teacher and then record in their diaries the main features of their chosen watering place, using these questions as a guide (depending on what kind of place it is):

In the case of a pond:

- Is it a temporary pond, or a permanent one?
- Does it dry up in the dry season?
- Is it formed by accumulated rainwater running down the slopes and collecting in a hollow?
- Is it the bottom of an old lake, or the place where a wadi spreads out and ceases to flow, the 'cutoff' of an **allochthonous** river, known as a 'marigot' in Africa?

In the case of a guelta:

- Is it a permanent body of water (most gueltas are permanent)?
- Does it result from groundwater rising and emerging through cracks in the soil – a kind of window into the undergroundwater table?
- Is it fed by a visible stream flowing from a spring where an **aquifer** meets the surface (usually on sloping ground)?

26. *Tifnitine* guelta, *Tassili N'Ajjer*, Algeria

Example:
Many gueltas are fed by hillside springs that gush out and tumble over waterfalls in mountainous parts of the Sahara.

- Does it form a natural reservoir in the rock?
- Is it protected by the natural features of the relief?

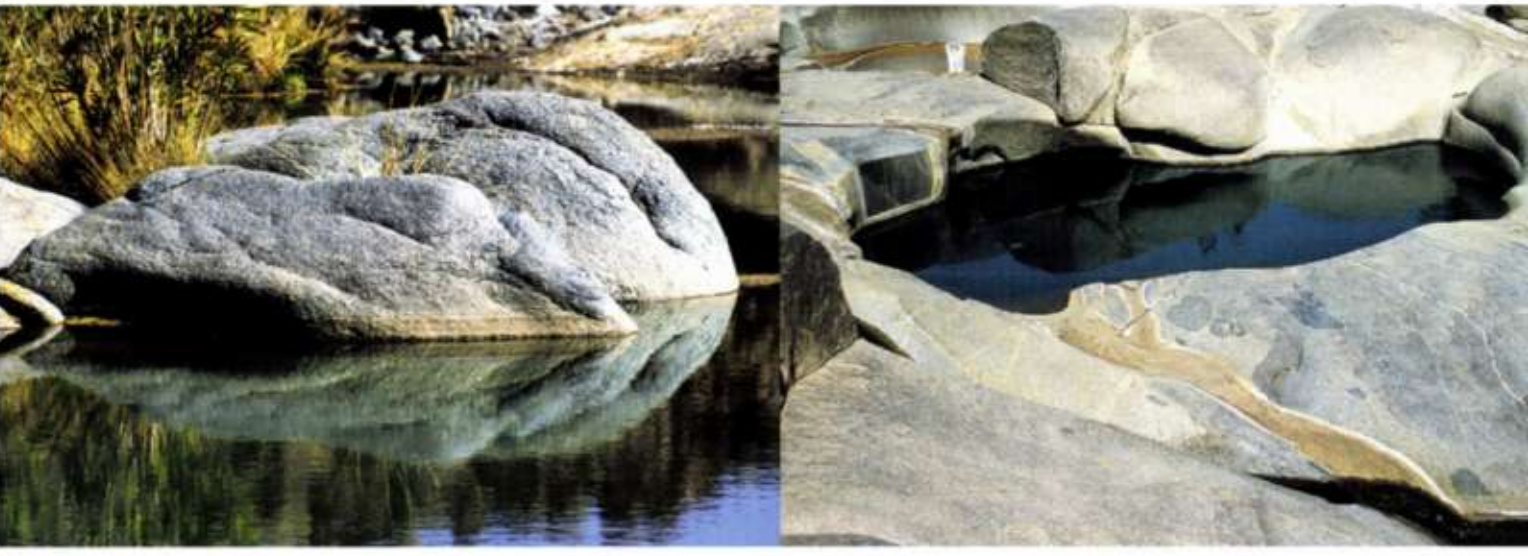
Example:
In Australia ancient laterite and sandstone hills such as the Olgas provide perfect sheltered spots for age-old gueltas.

In the case of a stream:

- Is its flow irregular? Where does the water come from?
- Does it flow quickly?
- Is its bed stony with steep sides, and does it flow down a slope that is already gullied?
- Are there any signs of heavy, intense runoff?

Example:
During heavy rainfall, streams in Central America cause flash floods, removing the top soil. They are then called **huaycos**, destructive torrents of water mixed with mud and stones, which flow swiftly down the mountainsides in the channels left behind by the **gullying** process.

► The pupils may write a couple of pages of brief notes in their diaries in answer to the appropriate questions for their choice of site.
► They then draw an initial sketch of the watering place; this marks the beginning of their research. They regularly make other drawings as time goes by, to show how the watering place changes with the seasons (stream in spate/running low; pond drying out/filling up).



27 and **28.** Guelta, *Hoggar Tassili*, Algeria

2. Study the natural and ecological functions of the watering place

►The teacher divides the pupils into groups and then gives their work the necessary background by looking at the watering place's ecological role in the ecosystem from different perspectives. The pupils study the aquatic biotope's geography and development over time through regular observation.

►One group examines the impact of the surroundings, the abiotic environment, on the watering place.
The group makes several attempts to calculate and measure the amount of water present, with the assistance of the water master and – through the teacher – the local scientific community.
- How often does it rain?
- How much water goes into the pond as it forms?
- Does the volume vary from one year to another, depending on the year's rainfall? Can it be estimated?
- Has there been more **areism** in recent years?
- Does water seepage through the soil have a major impact on the level of the pond?

- In the case of a stream, can its flow rate be measured (the number of cubic metres of water per second passing a given point)?
- Can the seasonal variation in flow be measured?
- In the case of a guelta, how much water is lost through evaporation between the end of the rains and their return?

►Another group considers the colour of the water and, with the teacher's help, makes several observations.
The colour of the water is a clue to the ecological functions of the watering place. What does the cloudy water of the pond indicate – brown, grey or greenish?
- The runoff which brought the water has been full of sediment.
- The pond is exposed to the wind, which deposits more sediment.
- There is a constant massive interchange between the pond water and the silt.

29 and 30. Temporary ponds ensuring water for cattle, Sahel

► The teacher continues:
• These sediments are often fertile: nutrients also are carried by the wind or mixed with the sedimentary clay.
• Furthermore, the temperature of the pond is close to that of the air.
► Together, class and teacher observe that a temporary pond in a dryland area is a fertile biotope as a whole, a place where silt and nutrient particles are brought from the surrounding slopes and deposited. Several successive life cycles will develop there within a short time (during the rains and the start of the dry season); these are species adapted to the particular living conditions found in temporary ponds – plants, crustaceans, amphibians and fish.
These species are not rare, for they are found in most ponds; but it is astonishing how well adapted they are to a life of discontinuities.

► For a contrast, the group observes the colour of a guelta.
What is the meaning of the water's colour here, often clearer than in a pond, and sometimes even crystal-clear, or green in places?
► The teacher points out:
• This is a sheltered biotope, protected from the wind and sometimes also from strong sunshine; evaporation may be less here, and the guelta is constantly being replenished through water infiltration.
• Some species can survive here that cannot live in ponds because the particle-laden pond water affects light transmission and impairs the photosynthesis of some algae and other aquatic plants.
• With their sustainable supply of water, gueltas are often permanent and sometimes very old. They can sustain a diverse biocenosis which develops over a long time.

► The pupils and teacher note:
The guelta is home to various kinds of plant: plants that live entirely submerged, algae, and plants whose roots are under water while their stems and leaves rise above the surface. Plants that take root in the guelta bed find the water sufficiently transparent, and get enough light. As it persists in time but is isolated in space, a guelta may sometimes be home to endemic local species (species found only in that particular region).

31

32

33

34

Gueltas help to preserve a heritage of flora and its associated fauna which is of great value for the maintenance of biodiversity.

3. Illustrate the watering place's ecological role in detail in the diary

►The teacher suggests to the pupils that they should portray the guelta ecosystem in terms of space and that of a temporary pond in time.

►For the guelta, the pupils begin by drawing a close-up of the watering place, viewed from above, showing part of the water surface and its surroundings. They may also draw a cross-section of the basin.
►Using shapes and colours, they draw – and in doing so learn to distinguish – the vegetation zones from the area around the water's edge to the middle of the basin.
• Trees, if any, grow on the banks. They may include palm trees like *Borassus niger*, or species from the tamarisk family (*Tamarix aphylla, Tamarix senegalensis*);
• Thick vegetation such as the dark green oleander (*Nerium oleander*) grows close around the guelta;
• The plants of the guelta's edge itself grow in the shallowest parts of the water: vertical clumps of bulrushes and reeds, including species of typha (*T. latifolia, T. elephantina, T. angustifolia*) and the common reed (*Phragmites communis*).
• Underwater plants meet in the middle of the guelta.
They comprise filamentous algae such as members of the *Characeae* family (if the water is clear enough), and aquatic plants with very fine close-set leaves which play an important role in maintaining the ecosystem by oxygenating and purifying the water. Milfoils (such as *Myriophyllum spicatum*) or pondweeds (*Potamogeton perfoliatus*), may also be found if the water is chalky or brackish.

►To complement their drawings, the pupils take specimens of each plant (or break off small sample pieces), from the water's edge to the centre of the basin.
They hang them to dry, press them between sheets of newspaper, and then paste them into their notebooks, keeping to the order of the drawings they have made.

►The pupils then see what animal species are associated with each plant community. Once again, the guelta is considered spatially, with its various micro-environments that form so many habitats.
The pupils describe these micro-environments and draw them one by one, colouring them in and showing the various species in their real-life situation.
►These can include:
• an underwater area, which may be well or poorly lit, inhabited by several species of fish, some of them perhaps unique to the locality.
Example:
Five local species of fish have been found in the *Ahaggar* gueltas in the far south of Algeria.

Preceding pages:

31. Women in their pirogues, *Ganvié*, Benin
© UNESCO/Georges Malempré

32. Man in his pirogue made with bulrush (*totora*), Lake *Titicaca*, Peru
© UNESCO/Georges Malempré

33. Activity on the banks of the river *Niger*, Mali
© UNESCO/Dominique Roger

34. Woman carrying a pile of wicker baskets on her head, *Cotonou* market, Benin
© UNESCO/Georges Malempré

35. Brackish pond with palms, typhas and juncus, *Aharhar* region, Algeria

36. Pond with *Nerium oleander*, *Juncus sp.* and palms, *Ihérir*, Algeria

37. Myriophyllum in the *In Houlila* guelta, *Tassili*, Algeria

38. Reflection of palms and phragmites on the pond's fringe, *Ihérir*, Algeria

• A bottom area with mud of varying degrees of saltiness, home to frogs and toads, amphibian larvae and invertebrates (fresh water shrimps).
• An area above the water, with resident and migratory birds nesting in the plants on the water's edge; also weavers, which are great seed-eaters, in the bulrushes. This space is filled with the many flying insects of the guelta: flies, mosquitoes and dragonflies such as *Hemianax ephippiger*, which are eaten by birds.
• A surface zone right on the water, which may include some rare **floating plants** in dryland areas and **emergent plants** where insects can lay their eggs and where their larvae grow and form an essential part of the diet of fish (especially dragonfly larvae).
• A peripheral border zone, where many kinds of mammal (cattle, dromedaries and antelopes) come to drink and cool down.
A guelta is of course a meeting place for nomadic people and their livestock, as well as the wild desert animals that quickly learn where these more reliable watering places can be found. Mammals standing around fertilize the ground near the guelta with their droppings, providing a habitat for insects, some of which are endemic (scarabs and **halophilic** beetles).

►The temporary pond ecosystem, by contrast, is portrayed as it develops over time.

39. Pond during the wet season, W region, Niger

40. Pond filling up, W region, Niger

► The pupils show the stages at which the various animals appear and disappear, depending on whether the pond is full or dry.
To do this, they take their original sketches showing the level of water in the pond at various times and link these with sketches of the species that correspond to the various stages of ecological succession.
► They also illustrate the species' adaptive abilities, or the strategies they use to cope with a cyclical lifestyle and the times when water is lacking: for all these species have had to adapt to the difficult living conditions of a temporary pond.
• For example, some frogs survive when the pond is dry by digging deep burrows in its clay bed: this is a form of behavioural adaptation. They leave these burrows the moment the rains return.
► First the pupils show them sheltering in their burrows; then they show them released by the return of the water.
• During the dry season in Arab lands, when a pond's water evaporates all the way to the bottom, a crustacean such as the shrimp *Triops granarius* dies: at least, the adults die. But before the pond dries out completely they have laid eggs, so the species survives in a form that can withstand the dry conditions. *Triops granarius* eggs can cope with temperatures of 90°C, and hatch within a fortnight of the water's return.
► Here again the pupils draw both forms of the animal (both are easily identifiable) as the water level changes.

► They draw the species in their diaries, as and when they appear, in concentric circles that indicate the depth of the water.
As soon as the rainy season begins, a thin layer of marsh vegetation begins to grow at the bottom of the pond, and young plant shoots appear around it. This is the first stage in the succession of life cycles.
► After sketching this layer of vegetation, the pupils then draw the crustaceans and amphibians that appear on the muddy bed, which is already full of organic matter.
Subsequently, if the pond is fed by the water from a wadi in spate several times during the rainy season, the rising water of the pond can bring fish, usually barbels such as *Barbus biscarensis* or *Barbus deserti*.

41. Pond with marabout storks, W region, Niger
© Michel Le Berre

42. Fossa reedbuck close to a pond, W region, Niger
© Michel Le Berre

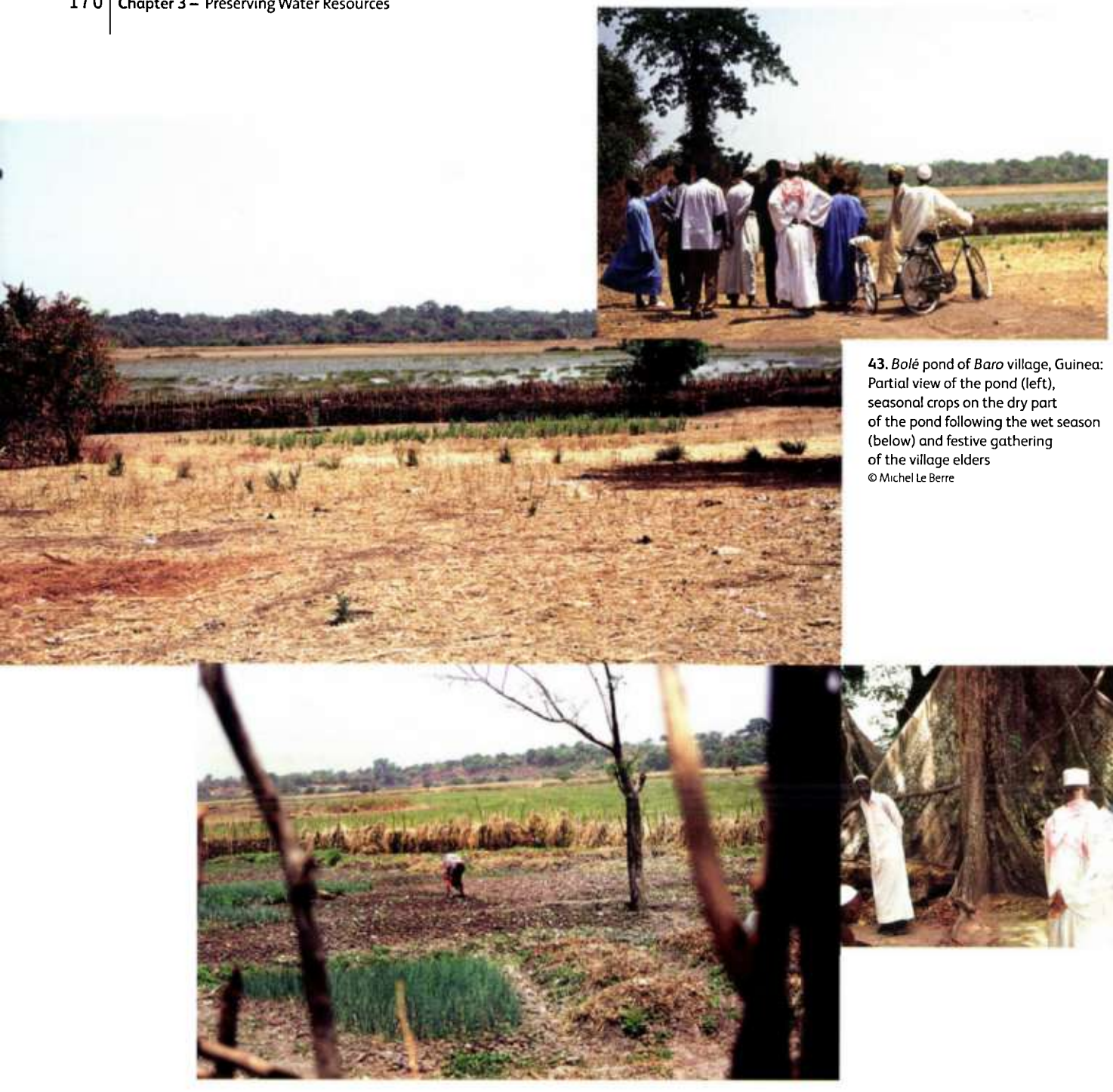
► The pupils may also draw catfish of tropical origin which are found in many ponds in Arab countries and Saharan Africa.
Many species in this family are large and carnivorous: they feed on other fish. When a pond dries out, fish like the catfish of the *Imirhou* wadi (*Clarias gariepinus*) manage to crawl across the mud, looking for another pond.
This is their adaptive solution to the isolation and discontinuity of their way of life, and a reminder of earlier times when the Sahara was a much wetter place.

► In carrying out this part of the activity the pupils come to appreciate the ecological importance of aquatic areas to the ecosystem and the conservation of dryland environments.
As the habitat for many animal species – some common, some unique to the locality, some rare and some endangered – these biotopes bear the hallmark of the surrounding biodiversity.
Furthermore, though temporary, they play a crucial role in the replenishment of the groundwater reservoirs, by percolation of water from their **underflow**.

4. Appreciate the watering place's direct utility to humans, by recording uses of it in the diary

► In their diaries the pupils list the ways in which the watering places are directly useful as fishing grounds and places with plants which often grow nowhere else, such as wild plants which can provide vitally important fodder in drought years.
These sites also provide natural sources of the drinking water that domestic cattle need.

► The class draws all the edible animals that can be caught by fishing in the pool, pond or stream.
► They draw the equipment needed: small boats, landing nets, fishing nets, improvised fishing rods, and fish hooks. Many will already have experience of fishing: they can describe a fishing expedition, including the particular techniques and skills that they have learnt.
► Then they note recipes for cooking the fish or other catch.
► At the same time, they illustrate the plants that are harvested from the water or nearby for various purposes: edible plants eaten uncooked in salads, edible algae, medicinal plants and fodder plants.



43. *Bolé* pond of *Baro* village, Guinea: Partial view of the pond (left), seasonal crops on the dry part of the pond following the wet season (below) and festive gathering of the village elders

5. Include in the diary a detailed account of the watering place's cultural functions

Finally, what part does the watering place play in the world of the imagination, in religious practice or in the sacred rituals of the local people?

►The pupils begin their research into the cultural role of the watering place by investigating the sacred character of rainwater to desert dwellers.

As surface water is rare and unreliable, and even the stock of undergroundwater is not inexhaustible – some groundwater reservoirs are replenished by floods while others are 'fossil water', never refilled – water is such precious and longed-for stuff that it has a very special place in the collective imagination and the creative work of the culture.

►In the many countries where the predominant religion is monotheistic (South America, Arab lands), the class looks for stories and other cultural expressions in which rainwater features as a gift from God.

►In many other countries where polytheistic religions are predominant or animism is widespread, the pupils describe the hero, spirit or character who personifies rainwater.
As something that may or may not be available, rainwater is often associated with a spirit.
Example:
Pupils in the African country of Mali can draw or write about the water spirit *Nommo*, who has extraordinary powers and takes many forms, some beneficent and some frightening: for this spirit can bring rain and prosperity – or punish neglect of its cult by sending drought and poverty.
►The class tries to represent the manifold aspects of the spirit, and connect these with the village organization of its cult.

►Working from this background, the pupils then go on to investigate and record the ways in which the pond, guelta or spring is associated with the veneration of water as spirit.
Recommendation:
If they cannot describe or portray rituals involving the pond which they are not normally allowed to attend (initiation rites, for instance, in which the neophytes are washed with water from the pond), the pupils can decide to concentrate at every stage on the significance of the watering place to the local community in terms of its heritage and mythology.
They use images conveyed by the traditional tales of storytellers as told by the 'griots' in Africa.

►They include in their diaries an account of the role played by the watering hole in the village's foundation legend, or the narrative of its ordinary history as told by the elders.
How is the pond associated with the mythological version of the community's history?
Is it somehow a gateway, a channel of communication or commerce with spirits?
In the stories told about it, does it have magical properties, or bring special benefits to the village?
►On the occasion of public festivals the pupils enhance their diaries with drawings of the masks, totems and sculptures used in the celebration of public rituals connected with the water of the pond.
Example:
A pond is often the site of major popular celebrations which draw people from an entire region and often involve dancing intended to celebrate and consecrate the water: one example is the *Bole* pond festival in Guinea.

►The pupils also consult the water master who – in consultation with others – organizes the villagers' access to water resources, the restricting of consumption and, sometimes, when resources are in short supply, rationing.
In their diaries the pupils write down the rules governing access to a water source (fishing, for example) and the distribution of water among the inhabitants.

►They also meet the water council of elders, many of whom are in charge of local water cults.
Provided such questions are permitted, the pupils question them about the offerings made or rituals performed to ensure the arrival of rain, the fertility of the land, or the abundance of produce from the water.

05 Clean Water for the Village: Map and Strip Cartoon

Level
advanced ★★★

Place
classroom and outdoors

Duration
6 sessions

Objectives

1. Discovery of the environment

By creating a local water map illustrated with various pictograms, the pupils assess the quantity and quality of surface water and groundwater resources in their environment.

2. Aptitudes

The pupils try out various methods and technologies for purifying, recycling and desalinating water; working on a manageable scale, they explore worthwhile remedies for tackling pollution and resource depletion; they then communicate these alternatives to the population in the form of a strip cartoon.

Methodology

1. Create a local water map

►With the teacher's help the pupils make a survey of the various places where local people access water resources.

Where do families go for drinking water? What sources do they use to irrigate their crops or water their cattle? What about washing clothes, dishes, etc.? What about personal hygiene?

►A large piece of paper is put up on the wall for the pupils to draw a map of the village and its surroundings. They mark the points of access to surface and groundwater for the various needs. Alternatively they could use an existing map.

►Marking access points on the map (in some situations there may only be a few), the pupils show wells, drinking fountains, pumps and places where water can be taken from a spring or from the edge of a pond, lake, stream or river.

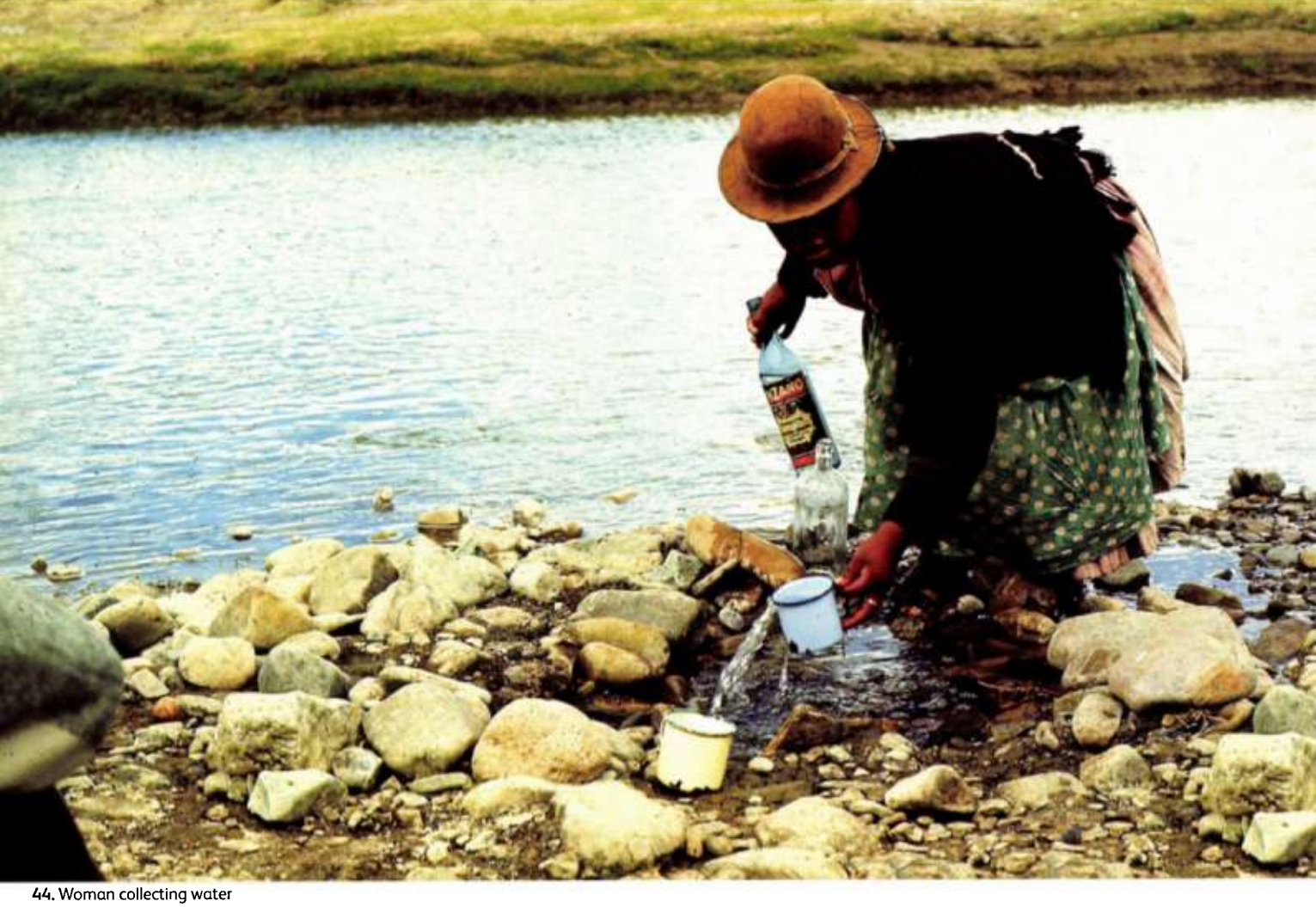
Rather than actually drawing pictures of the sites or methods of water access, the pupils devise a set of icons or pictograms to show, for example, whether groundwater is drawn up by means of a balance-beam well or animal power; collected from a temporary well hand-dug in the sand or from a deep lined well; whether a pump or pulley is used; or the means of bringing water to the surface through a network of underground channels (the *foggara*, *quanat*, or *khettara*).

►They then draw the pictograms on the map to indicate the access points.

►In each case, a coloured dot shows how the water is used.

Examples:

- a blue dot for drinking water (drinking, cooking);
- a green dot for irrigating gardens and fields;
- a mauve dot for personal hygiene;
- a yellow dot for watering animals, etc.



44. Woman collecting water from the river, Bolivia
© UNESCO/M. Zevaco

► Next, the class evaluates the quantity and quality of surface and groundwater resources based on an examination of the supply points.
The teacher provides a set of questions, and the pupils set about answering them with the valuable assistance of older members of the community and those responsible for managing water resources.
• Is the availability of surface fresh water limited?
• Has it diminished overall?
• Were there **puisards** (shallow man-made wells) where undergroundwater used to be available, or where springs used to well up but have now disappeared?
• Is there plenty of water in the wadi or river during the rainy season?
• Is there a seasonal rain-fed pond which has now become unreliable?
• Does undergroundwater storage provide some compensation within the ecosystem for the irregularity of runoff water?
• Do shortages of drinking water sometimes cause problems, indicating that too much is being pumped from underground resources?
• Has the ecosystem deteriorated?
The pupils question the elders in detail on this point: do they remember any species that have now disappeared?
• Has local biodiversity diminished since a particular date in the past (less species variability, genetic diversity or ecosystem diversity)?

► They devise another set of symbols to indicate the water level of each watering place (or the flow rate, or the reliability, as appropriate to the type of source).
► The new system of pictograms is used to show whether the water resource is being conserved or whether, on the contrary, it is being neglected and depleted.
They also mark the site of former watering places that are now dried up or depleted.

► The teacher explains how excessive pumping of groundwater – sometimes the only source of drinking water in dryland regions – can impair the quantity and quality of water.
Underground fresh water becomes brackish as salt moves in.
► The class takes samples from various water access points, and puts them in bottles or transparent containers.
► The pupils label each container to show the water's origin; they describe the odour, colour and (if appropriate) the taste of the various samples, using precise adjectives.
These descriptions of the quality of the water may be added to the map in the form of short notes.
Example:
Colour: dark
Odour: acrid
Taste: not tested.

► With the assistance of the water master and health experts, the pupils identify any sources of pollution that might be affecting the taste, odour and colour of the water, or making it brackish or corrosive.
► Here too, they devise a system of pictograms to describe each pollution source, which may be:
• direct chemical pollution from the use of fertilizers or pesticides in farming;
• water pollution from toxic waste dumped nearby;
• pollution from mine or quarry waste;
• pollution with industrial waste water from chemical works.
If the water is brackish, is this a result of human activity? For example:
• poor drainage of irrigation systems?
• water evaporation caused by a change in land use?
• seawater intrusion underground due to excessive pumping?
• direct chemical pollution?
Lastly, pollution may also be:
• bacteriological (dysentery or cholera pathogens);
• zoological (various pathogenic organisms: the larvae of malarial mosquitoes, bilharzia, flukes, ascarid worms).

► The teacher points out that in most dryland countries the main cause of disease (80%) is bacterial rather than chemical contamination of water.

Before they put the pictogram for a specific pollution source on the map, the pupils check whether the watering place is in fact polluted (or at risk of pollution).
► To do this, they question various water users and consumers with different needs.
Where they cannot find out for themselves, they ask simple questions:
• Are the various wells that provide local drinking water lined?
• Do they have a protective cover?
• Are the wells fenced off from cattle?
• Do they have a raised kerb or a paved area around them to separate the water from the mud or ground trampled by cattle?
• When water is collected from a torrent or spring, is drinking water collected upstream from where cattle drink or women wash clothes?
• Are drinking water containers protected or covered in people's homes?
• Are watering places where people wash and bathe also used by animals or for other uses such as farming or manufacturing?

► Combining these answers with the information provided by the water master and the doctor

45. Young herder watering his cattle at the village pulley well, *Abidi*, Senegal

46. Donkeys drinking, *Abidi*, Senegal

or healer, the pupils put pictograms to show where any watering place is polluted or constantly at risk of pollution.

2. Interpret the water map

Once the map is finished, the pupils have an overview of the status of their neighbourhood's watering places.

► Pupils and teacher together read the icons to assess the exact state of surface and groundwater resources, and understand how they interact.

► In this compact representation they can see the shortcomings of the water supply system and the pressure exerted by the community on groundwater reserves; they realize that these reserves are not inexhaustible and are barely being replenished, for the most part by water percolating down from the beds of rivers and streams. They come to appreciate the real danger that the community may see a drying up of these shallow underflow-fed aquifers, the only permanent water resources in dryland regions.

► Here the teacher explains the percolation and storage of water underground, along the beds of rivers and streams and also beneath standing water (permanent lakes and temporary ponds).

► The class can assess the extent of groundwater depletion by examining the condition of surface plants which are normally quite at home and drought-resistant, but which may dry out or wilt because they are no longer managing to take in water through their roots.

► The teacher points to the destruction of neighbourhood ecosystems that are of vital economic, social and ecological value to the population.

► By reading and interpreting the water map the pupils can also see how insufficient water quantity leads to inadequate purity and cleanliness as well.

The pictograms show how overexploitation of natural resources connects with lower water quality. By interpreting the icons, the pupils can identify improper behaviour, failures in collective responsibility, and mismanagement of water.

► The teacher goes on to remind the class that water is a common, universal commodity. It is vital to the community – and indeed to humanity – and something shared by us all.

Its cyclical story shows that water is one single substance: the water we drink is the same water that has already served many uses and performed all kinds of functions for an incalculable number of people before us.
So we have to take care of it: to respect its purity as much as possible, to use it sparingly, and to manage it in a fair and sustainable way.

► Then the teacher encourages the pupils to think about ways of promoting the conservation and sustainable use of local water resources.
Various methods or technologies can be mentioned and presented to the pupils: these include some interesting possibilities such as the purification and recycling of waste water and the use of solar energy and other renewable energy technologies for desalination.
For instance, as part of the SUMAMAD project mentioned earlier, the research team for the *El Omayed* Biosphere Reserve (the project's selected Egyptian site) has designed a system for desalinating and purifying the brackish water from the region's wells using the principle of evaporation and condensation explained on p.177 below. The water flows under gravity from a tank to four distillation units that use solar energy to separate the salt from the water.

3. Conduct decontamination experiments in class

With the teacher's assistance, the class tries out a number of practical decontamination or treatment methods on waste water or brackish water at school.
How can dirty, particle-laden water be given an initial cleaning?
► The teacher suggests the sand filtration technique, which removes **turbidity** from the water, along with organic matter in suspension.
► The class gets a sieve with a fine filter.
► A fairly thick layer (a few centimetres) of gravel is placed on the filter, followed by a thicker layer of sand and then another, thinner layer of gravel. The layers of gravel help to keep the sand in place.
► A large quantity of waste water containing grease, particles of organic matter and other pollutants is then poured on, and observation begins...
The layers of gravel and sand catch and extract the water-borne particles, depending on their size: first any lumps of organic matter and debris, then small insects and organisms, algae, zooplankton and suspended particles.
► On the surface of the sand beneath the gravel the pupils can see a film of dust, particles and microorganisms that have been filtered in the process. This forms a kind of 'skin' or biological film.

Stages of a water purification experiment using solar distillation


1


2


3

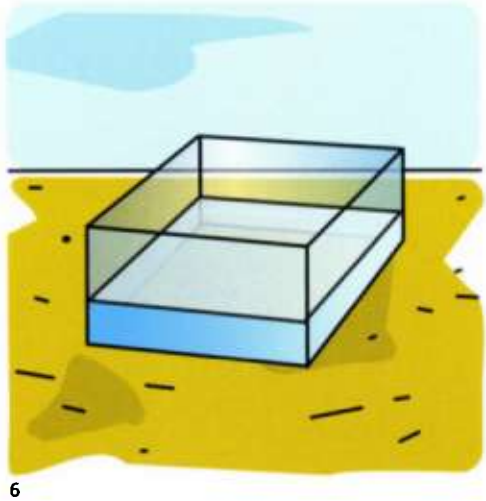
► At the end of the demonstration, the teacher explains that there are sand-based water filtration arrangements designed to provide an economical water **purification** method for communities to use.
The teacher describes a system which generally comprises a basin containing a layer of untreated water, a bed of filtering material consisting of sand with in-built drains, and finally, a filter regulation and control system.

► The class then carries out an experiment in water purification by solar **distillation**.
Distillation, too, is used in many parts of the world to decontaminate water, and also to turn brackish water or seawater into fresh water.
► The pupils obtain a big, round plastic basin, preferably dark in colour, for such colours – especially black – will always absorb more heat (1).
► They get a container full of brackish water from a pond or well and pour it into the basin (1).
► They then rinse the empty container carefully and put it in the middle of the basin (2); they cover the basin with a sheet of clean plastic, preferably transparent (3).
► The sheet of plastic is held in place by string tied around the basin, and is made into a funnel shape by placing a stone in the centre. The weight of the stone pushes the plastic sheet down in the form of a cone towards the container inside (4).
► The pupils place the still in the sun (5).
Its heat warms the water in the basin, which quickly evaporates.
► The water vapour condenses on the inside of the plastic sheet, runs down the cone and drops into the container (5).
After one or two days of exposure to the sun, the container is full.
► The pupils remove the plastic sheet and observe what is left.
A residue of salt or matter previously suspended in the brackish water has been left as a deposit on the bottom of the basin.
The water in the container has been purified both chemically and bacteriologically (6).

► The pupils taste this water. Does it taste good?
However, it does not meet all the criteria to qualify as drinking water: ideally, to be totally biocompatible with human beings, water should contain a small quantity of minerals and be 'alive' in the sense that it may contain certain living organisms (bacteria) that are not harmful for people. Distilled water does not contain any minerals, and is purified to complete clarity.
► The pupils can learn how to remineralize water (by adding clean clay, for example).


4


5


6

Stages involved in making a water purification station using the lagooning process

1 2 3

Nevertheless water obtained in this way (through solar distillation) does have the advantage of preventing bacteriological contamination among people. It is therefore very widely used in many dryland countries: one of its benefits is that it significantly reduces the number of diarrhoea cases among children.

►The class records the various stages of each experiment in a written account, so that they can be shown in a strip cartoon (cf. para. 5, below, p.179-180).

4. Create a miniature water purification station based on the lagooning process

One last experiment may be possible: a larger-scale decontamination process designed to purify water for use in the garden.

Remarks and suggestions:

This venture is more ambitious than the previous experiments, and demands long-term commitment from the class, not for the construction of the system (which does not take long) but in keeping it under regular observation. It takes some time –several months– for the benefits of the biological purification process to develop.

A site needs to be chosen where the soil is impermeable enough to retain surface water effectively.

It is also better if the site is on gently sloping ground.

Lastly, the class will need expert advice and constant support from knowledgeable adults.

►Towards the end of the wet season, when rainfall is lighter and more intermittent, the whole class, assisted by several volunteers from the local community, digs two hollows at the chosen site.

The first hollow, measuring roughly 3x4 metres, is situated higher up the slope.

The second hollow, lower down, may be smaller.

Both hollows are dug to a depth of 50cm, and water will flow under gravity from the higher one to the lower, depending on how quickly the former fills up (1 and 2).

►The pupils do not put any plants in the first hollow, which is partially filled with recent rainwater (2).

►The pupils then invite the local population to pour all their waste water (water from washing up, bathing, hand-washing and laundry) into this hollow. It might even be possible to arrange for waste water from agriculture to flow directly into it (4).

►For purification in the first hollow, the plan is to rely on the effects of sunlight and the rapid growth of algae which photosynthesize, proliferate and provide oxygen for the kinds of bacteria which need oxygen to survive (known as 'aerobic bacteria').

These colonies of aerobic bacteria break down the organic matter suspended in the water, releasing the nitrates and phosphates that are then consumed by the algae (5).

4

5

6

In this way the most polluting mineral salts are assimilated, and a large proportion of the suspended matter settles at the bottom of the hollow.

► Still with help from adult volunteers, the pupils build a watertight wall along the edge of the hollow on the downhill side, to control the flow of the water.
They make this wall lower in the middle so that the water can overflow into the lower hollow.

► They then plant 'macrophytes' (big plants) in the second hollow (3).
► For this, they get marsh plants, in particular the common reed (*Phragmites communis*) or broadleaf cattail (*Typha latifolia*), from the edges of an existing pond or lake.
They choose healthy specimens, which they plant out along the edges of the hollow while keeping the water level low.
► The pupils take turns to ensure that the hollow does not dry out and is fed by fresh rainwater or another available source. This helps the plants to take root quickly.
As the water from the first hollow reaches them, the plants assimilate the rest of the mineral elements present in the water, particularly by fixing the compounds of phosphorus or nitrogen, and any detergents – sometimes heavy metals, as well (5).
► The pupils may introduce floating plants such as duckweed, which is an effective purifier of heavy metals.
► They work regularly to make sure that the water can flow, by cutting plants that would otherwise proliferate and quickly choke the hollow.
Any remaining suspended particles of organic matter will be eaten by zooplankton associated with the plants (daphnia, insect and mollusc larvae) (5).
► After the waste water has spent two months lying in the hollows the pupils may re-use it, after first testing its quality. If it is clean and pure enough, it may be used to irrigate seedbeds or water their garden (see Chapt. 3, act. 7, p.120) (6).

5. Create and distribute a strip cartoon on the basis of these experiments

► In this final section the class creates a strip cartoon which illustrates, in a number of picture strips, the various solutions they have investigated for tackling pollution and resource depletion: filtering, distillation and purification by lagooning.
► In order to keep a common theme in the drawings, the teacher and the class invent a character: the hero of the strip cartoon who represents all the pupils at once. The pupils can nonetheless draw this hero in company with other, anonymous children or adults in order to vary the composition.

This central character, who instigates and guides the filtration, distillation or purification project, must be readily identifiable by everyone and easy to draw.

► The teacher divides the class into several groups according to the number of scenarios planned. Sub-groups within these groups will draw strips for the scenario, one strip each. It is best to divide each scenario into strips, and to focus on one or two messages per strip.

Examples:

Sand filtration scenario:

1. Strip showing the filter being made;

2. Strip showing the filtration experiment itself.

Lagooning scenario:

1. Strip showing the first hollow being dug;

2. Strip showing the second hollow being dug and planted;

3. Strip showing waste water being poured into the first hollow, the purification process and the water overflowing from one hollow to the other;

4. Strip showing the purification process in the second hollow, the purified water being collected and then used for irrigation.

► Before starting to draw the strips the pupils agree on a common style.

• Each group practises drawing the main character.

• Each illustration is first tested within the group to ensure it is legible, that the objects and characters are recognizable and the message conveyed by each image can be understood by all.

► The pupils then produce the strips for each scenario; they draw the hero in a real-life situation, trying out the three techniques of filtration, distillation and purification. Their drawings also illustrate the pleasure of rediscovering the look and taste of clean water, which should be as clear as possible, using light and colour to set off its visual qualities.

► When the strip cartoon is finished, the pupils distribute it to all the local people.

47

47. Young scientist,
Aral Sea water analysis laboratory,
Aralsk, Kazakhstan
© UNESCO/Zhanat Kulenov

48 and **49.** Studies and tests
carried out by scientists
of the Institute of Geography,
Aral Sea, Kazakhstan
© UNESCO/Zhanat Kulenov

48

49

50

52

50. Woman washing dishes,
Koloni-Boundio village, Mali
© UNESCO/Inez Forbes

51. Woman drawing water
from the cement-covered village well,
Koloni-Boundio village, Mali
© UNESCO/Inez Forbes

52. Well, *Hassi Khalifa*, Algeria
© Olivier Brestin

51

06 Panelled Fresco of the Village Water Management System

Level
advanced ★★★

Place
classroom and outdoors

Duration
6 sessions

Objectives

1. Discovery of the environment

The class considers the impact of irrigated agriculture in terms of resource depletion, and rediscovers traditional techniques for gathering, collecting and transporting water by completing discovery trails, by exploring and by drawing pictures, so as to appreciate the elegance and ingenuity of these systems and techniques.

2. Knowledge and comprehension

By producing a series of large drawings to create the fresco, the pupils highlight the ecological importance of the traditional village water management system, whether it is a sophisticated irrigation system drawing on groundwater or an organized network of open-air canals and reservoirs.

Methodology

1. Survey the landscape for stone constructions designed to capture humidity and runoff water

►With guidance from their teacher the pupils search their surroundings for different examples of stone structures around the countryside.
They may find stone walls, piles of stones, **tumuli** or similar structures, cisterns covered with a pile of limestone rocks, barriers or diguettes in the gullies of slopes, stone cordons, and so on.

53. Landscape dotted with low stone walls, *Honaine* region, Algeria
© Olivier Brestin

54. Traditional stone house, *Ihérir* wadi, Algeria
© Olivier Brestin

55. *Kesria* in the *foggara* among palms in *Tolga*, Algeria

Examples:
The tumuli or circular stone houses (*specchie*) found in some countries in the Mediterranean region; **gabions**, which are stone diguettes enclosed in a metallic frame, a technique exported from Europe to combat erosion and now widespread in African countries; and jar cisterns, ancestral reservoirs comprising an enormous jar set in the ground and covered with a pile of limestone rocks which capture moisture in the atmosphere: these are very common all around the Red Sea.

► The pupils wander around the area where these stone structures, some of them very old, form part of the landscape, creating little nooks, hidden spaces and micro-environments offering many treasures to be discovered. They move around and explore this rough terrain.
► The teacher explains that these stone structures play a dual role in water management. Firstly, they make it easier to retain and collect runoff water by allowing more of it to sink into the ground; secondly, where the air humidity is high they allow water to be extracted from the atmosphere by concentrating and condensing the moisture.
► Near a line of stones, the teacher continues:
Low walls are built on flat or sloping land in runoff areas.
They lessen the force of the runoff by retaining water, slowing down its flow through the fields and making the water spread across the land so that it seeps more readily into the soil instead of being lost on the surface.
Where this method is not used, wadis often erode the land into gullies by the force of their current, and seep all too soon into the sand where they evaporate due to the intense heat.

► The class learns how to study the micro-environment created by the wall.
Local plants grow along the line of stones because humus is concentrated in these areas. The wall also retains atmospheric humidity in the hottest part of the day letting it sink into the ground; it makes shade and provides shelter from the wind and heat.

► The pupils discover these plants and draw them; sometimes they are rare ones, hidden treasures which can grow here – though nowhere else – thanks to this ancient and ingenious water catchment technique.
► They produce detailed drawings, sketches of the surroundings and then technical drawings of the wall itself, observing the stone structure: was it built with schist blocks, limestone boulders, quarried stone, coarse lumps of granite or rough gravel?

► The teacher makes the exercise even more relevant by getting the pupils to look closely at the rocks used to construct a tumulus or shelter (*specchie*, roofed cistern) or to cover an open cistern at ground level.
► The teacher explains that these porous stones provide water both day and night.
• In the daytime, especially at the end of the rainy season, the wind in arid or semi-arid areas still carries a little water vapour; this penetrates gaps in the stone-work, which is cooler inside than outside: the rapid fall in temperature condenses this water vapour into droplets which fall and are absorbed into the soil or accumulate in cavities.
• At night condensation takes place on the stones' outer surface, which is colder than the air; the dew that accumulates there seeps down through gaps in the structure and collects inside.

► Returning to the classroom, the pupils set about composing the initial panel of a fresco that tells the story of the traditional water management system.
On this first panel they make big drawings of the various stone structures they have observed, and the associated techniques used for catching and managing surface water.

2. Study the use of terraces in the landscape and recognize terracing as a method of surface water management

► If the countryside around is suitable, the pupils go outside to inspect the terracing of slopes. They walk these giant staircases from the bottom to the top, also wandering along the contours at different levels; they discover the micro-environments at each level and the crops associated with them, survey the pathways from one level to the next, explore hidden recesses and organize games or a treasure hunt among the terraces.
► They stand at the top and try to draw the terraces from above in coloured crayon.
They sketch:
• the contour lines on which the terraces have been built;
• the winding lines of each level, sometimes stretching from one terrace to the next over long distances;
• the boundaries of the various plots, with their different shapes along the contour line;
• the patchwork mosaic of colour and shading formed by the different crops.

► The teacher introduces the notion of **contour lines** joining up all the points at the same altitude.
Among other things, a set of contour lines can be used on a map to show hills.
► The teacher tells the pupils that terraces are built on the contour lines where low stone walls are constructed to support the flattened surface of earth.
► The teacher continues by explaining that terraces make it easier to manage surface water properly, allowing the moisture to be spread throughout the soil and, in particular, helping to combat erosion.
► The pupils can see for themselves how the edge of a terrace, formed by the low wall, leans very slightly in the direction of the slope, enabling runoff water to flow steadily without causing erosion. In this way terraces help to lessen the erosion caused by torrential rain.
► Lastly, the teacher explains that some terraces are even more sophisticated in their design as water catchment and management system.

► The top layer of fertile soil is spread over a layer of small stones, which itself overlays another layer of bigger ones; all this helps to drain irrigation water. Here again the effect is to promote seepage and avoid surface erosion: two features that must be combined if surface water is to be managed properly.

3. Create the second fresco panel, including aspects of a surface water management system

► Returning to the classroom, the pupils start on the second fresco panel.
► Still working on a big scale, they draw a terraced agricultural landscape with stone walls, terrace levels and access routes (often small staircases built into the stone walls).
► They make sketches summarizing the way in which these features have been created:
• The building of the wall, from its foundations on large stones to the pebbles stuffed into the cracks;
• The levelling of the terrace, and the ingenious result: a plot of land now flat and ready for cultivation, won from a previously barren hillside using only the material of the ground itself.

► In one corner of the panel the class adds a written account of the various stages in the development of these unique landscapes, bringing out the complementary relationship between people and nature.
The intention is to convey:
• How people work patiently to redesign dryland slopes, respecting their natural contours;
• How they recognize the hillsides' dips and faults, filling them with gravel to prevent landslides, building low stone walls and raising the level of the ground layer by layer to create areas for cultivation;
• How people become in this way the creators of landscapes: true landscape artists.
Example:
They may mention the magnificent terraces of Ethiopia, northern Cameroon, the Andes or Arab countries, particularly Yemen, where stone barriers are built along the contour lines to catch runoff water and distribute it over the plots of land.

56 and **57.** Crop terracing, *Socaire* region, *Atacama* desert, Chile

56 57

58

60

59

61

58. A woman filling up at the water source, isolated Andes village, Ecuador
© UNESCO/ Jean Cassagne

59. Experimental plantations of olive trees in croissant-shaped basins retaining water, *ICARDA*, Syria
© Thomas Schaaf

60. Irrigated fields, Mexico
© UNESCO/ France Bequette

61. Aspersion irrigation helped with overhead watering pipes, Senegal
© UNESCO/ Dominique Roger

► On the central drawing of the panel, the pupils use colour to show how crops and vegetation alternate at different levels, and the association of different species at the same level.

Example:

In the Andes, scientists have identified up to fifteen different ecosystem levels where, depending on the height, farmers grow a combination of plant species in association. The most common crops are maize, beans, sweet potatoes, barley and quinoa.

► Crops may be represented on the fresco by the use of various materials and collage techniques.

► Also on the central drawing of the panel, the pupils show the various water management processes made possible by terracing.

• They use arrows to show how rainwater is collected at the various levels and distributed naturally along the slope.
• They also show how runoff water is slowed by building the terrace at an angle in the direction of the slope.
• If this runoff can be held back by stone barriers, the pupils use arrows to indicate the water flows.
• In the case of built-up terraces they show how surface water percolates through the soil.

Some terraces have a rainwater catchment and transport network; and this type of network can also be found where there is no agricultural terracing.
►So the class sets about portraying the surface water management system of their own village (if there is one, with or without terracing).

►The pupils locate rainwater reservoirs and any network of transport and irrigation channels.
►If the network includes terraces, the pupils find the answers to the following questions:
• Is water stored on the hilltops in reservoirs upstream from the irrigation channels?
• Does the water come from snow-melt, streams or torrents?
• Is the water distributed from terrace to terrace by stone channels?
• Is it distributed through pipes of different sizes, to control the volume of water according to the size of the plot?
• Are the pipes made of bamboo, wood or stone?
• Is the water distributed through irrigation channels shared, for example, by the inhabitants of the same village located on the hillside itself?
►Once they have clarified these various points, the pupils can draw the whole water management system on the fresco.

►If the network is not on a terrace, the pupils identify the water catchment reservoirs in the area, usually at the bottom of hills or in runoff areas.
• Are they simple hand-dug reservoirs in the ground, such as the *johads* in India?
• Do they take the form of one or more dams which hold back the runoff water of a wadi?
• Are mobile tanks carried by human beings or animals to take water from these reservoirs to orchard or crop irrigation points?

►Here too, once these questions have been answered, the pupils draw the village's surface water management system on the fresco in a vivid, colourful way.

4. Illustrate the connection between proper use of water and the struggle against erosion on the third panel

►Along with their teacher, the pupils visit areas that have been heavily eroded by rainwater.
►They see the carved-out ravines for themselves, and learn of the various techniques used in their neighbourhood to reduce this **gullying** and its effects.
Often these involve stone-built barriers to filter and restrain the force of the current and to promote seepage into the ground.
Where anti-erosion barriers are not sufficient, the pupils observe the active part played by new vegetation, or by a newly planted area of woodland above heavily eroded areas.

►By visiting several affected sites the class comes to a general appreciation of reafforestation, and its importance for the village's water management.
►The teacher explains:
• Where there are no terraces, reafforestation is essential for combating erosion and preserving water resources.

• If hillsides or other runoff areas are bare of vegetation, erosion will silt up reservoirs and water will not percolate down into the water table.
► The teacher stresses:
Water catchment, reafforestation and action to combat erosion are inextricably involved in any genuine attempt at rehabilitating degraded land.

► The pupils then focus on planting methods associated with suitable irrigation techniques.
► On the third fresco panel they make a series of drawings illustrating how trees are planted on hillsides and a crescent-shaped hollow is dug at the foot of each.
Example:
In Syria, Tunisia and many other countries these shallow depressions, often strengthened by a ring of stones, collect the water needed by olive trees and help to keep water in the soil.

► Likewise the pupils illustrate a technique of putting semicircles of stones in staggered rows above a planting hole where the hillside is steep.
Example:
In Africa, manure is placed in a hole and a few millet seeds are then sown. The water retained by the semicircles of stones facilitates the growing process.

► On this panel the pupils also illustrate the **zaï** technique, in which planting holes are dug and then enriched with fertilizer.
They use comparative drawings to show how, during the dry season, the diameter and depth of the hole is widened and water and manure are added.
Once again, the combined action of water and fertilizer enables the crop – millet or sorghum – to survive for long periods without rain.

5. Use the fourth fresco panel to show traditional methods for extracting groundwater

► The pupils survey their neighbourhood for one or more traditional techniques used to draw groundwater to the surface.
Most of these systems are based on the sustainable use of resources, and preserve the water balance of the aquifer – for example by maintaining an exchange between atmospheric and soil humidity. One example is the system of **foggaras**, underground channels for collecting water also known as **khettaras** in Morocco and **quanat** in Central Asia (Iran, Syria).
► With their teacher's help the pupils examine these systems and learn how they work.

► They begin by putting them in context.
• A traditional wooden **noria** (waterwheel) often supplies a network of basins and channels; it is normally located near a river which provides a regular underflow in an arid area or in a place where there is direct access to the groundwater reserves.
• The *foggara* system is bound up with the context of the traditional oasis, and governs all that happens there.
Since the system depends on gravity to transport the water, the oasis must be located in a valley or at the foot of a fault so that it is below the level of the water table.

► At this stage of the activity, the pupils are given some instructions to explore the water management facilities by themselves; they wander about with their notebooks and are encouraged to sketch their surroundings.
► They capture the magic of the scene, the visual impact of a bucket wheel, the architecture it belongs to, and the series of basins.

62

63

64

62. *Shallaleh Saghireh* village, *Khanasser* valley, Syria
© Thomas Schaaf

63. *Shallaleh Saghireh* villagers, *Khanasser* valley, Syria
© Thomas Schaaf

66

65

64. Exterior canal of a *quanat*, *Shallaleh Saghireh*, Syria
© Hélène Gille

65 and **66.** Vertical trap door leading to the underground canals of the *quanat*, Syria
© Hélène Gille

67. Group of villagers, *Shallaleh Saghireh*, Syria
© Thomas Schaaf

68. *Quanat* storage basin, Syria
© Hélène Gille

67

68

69

70

69. Traditional *noria*, *Hama*, Syria

70. Hydraulic *noria* wheel, *Hama*, Syria

► They draw the oasis from different angles and at different levels of detail, as a microcosm which, though it may not portray the ideal image, the 'garden of delights' or *Jenna* of the Koran, is nonetheless a green space where the local people can relax and enjoy themselves.
► They sketch the surroundings: the palm grove and the rows of crops that not only feed the population but also provide it with a wealth of images and cultural reference points.

► The teacher continues by explaining the ecological significance of water management systems in dryland regions.
► The teacher describes one or more systems in detail:
• The underground channels of the *foggaras* collect water deep underground and bring it to the surface at the oasis because they are placed in the ground at a slight downward angle (dropping one or two millimetres per metre).
• These almost horizontal drainage channels collect the water contained in the porous layers and bring it under gravity to the oasis all year round.

► Then the teacher makes a series of points:
• The system protects groundwater reserves, since they are used sparingly and sustainably, unlike certain electric pumping methods which dry out aquifers, often irreversibly.
• Since the water flows under gravity alone, the ground is not scraped away nor are the channels damaged by underground erosion.
• The water is collected and transported underground, avoiding losses through evaporation.
• Salinization, high levels of evaporation and pressure on water reserves in arid regions make it inappropriate to use sprinklers or to water crops heavily in such places; the use of subterranean resources and irrigation by measured flooding, as provided by *foggaras*, is far more appropriate.
• Lastly, when the water reaches the oasis its use is regulated by communal water authorities; it is shared out by volume and stored in basins, proving that the whole system is designed with sustainability in mind.

► The pupils see the truth of this for themselves as they closely inspect the existing systems.
► They examine the water management process of greatest relevance to them in detail, breaking it down into its various stages:
The mechanical system of the *noria* relies on the principle of a water-driven chain carrying a series of trays or buckets which pull the water up; this system can also be used to measure and regulate the quantities of water used, in accordance with the resources available.

► Back in the classroom, inspired by what they have seen and sketched, the pupils create the final fresco panel.
• They show the water flowing in the *foggara*, from the first shaft up in the hills to the plots of land irrigated across the oasis.
• They begin this fresco panel by showing the scale of the water management system:
The movement of water through underground channels, the large number of vertical shafts that aerate and humidify the system, and provide access for maintenance.

• Then they set about depicting the visual aspects of the oasis irrigation system:
– The curious shape of the catchment basin or *quasri*, at the end of the channel where the water emerges from the ground;
– The evocative contours of the dividers, or kesria, which measure and distribute the water among users;
– The many-branched network of open-air channels or seguias carrying the water to the various *majen* (holding basins) before it is used.
– The water penned in the *majen*, before it is let onto the plots: two successive stages to illustrate 'water times' and the use of a system for 'taking turns' at water use.
– The colour and materials used in the original design of the system (stones and a mixture of straw and clay for *foggaras*), which ensure that it fits harmoniously into the landscape of which it forms an integral part, with no visual pollution.

6. Include more recent – but still sustainable – water management techniques in the fresco

► To conclude this activity the class includes on the various panels some drawings of water catchment and irrigation techniques that have recently proved to be particularly suitable for arid regions.

► On the first panel, the pupils draw an atmospheric condenser used to capture the moisture in the air through a concentration and condensation process, such as the fog catchers used in Latin America (Chile, Guatemala).

71

72

71. *Seguia* (an open-air irrigation canal) in *Taghoucht* oasis, *Tinjdad, Errachidia*, Morocco

72. Distribution basin of *Taghoucht* oasis, *Tinjdad, Errachidia*, Morocco
© Alexander Otte

73. Professor Sayyed Ahang Kowsar accompanying a group of young children discovering their environment, Iran
© RSCN, Jordanie

74. Irrigated fields with secondary and tertiary irrigation canals, *Taghoucht* oasis, Morocco
© Alexander Otte

75. Irrigated fields, *Taghoucht* oasis, Morocco
© Alexander Otte

74

73

75

► They draw the polypropylene mesh stretched between two posts at right angles to the prevailing winds, and the water collection process in which belts of persistent fog passing through it form water droplets on the mesh which then flow along a series of gutters into a reservoir.

► Lastly, on one of the panels showing irrigation techniques (whether based on traditional jar cisterns near crops, or underground reserves brought to the surface), the pupils illustrate the drip method of irrigation.
► Their drawings are designed to explain the importance of this technique in arid regions: they show how the drip irrigation system works with perforated tubes installed on the surface of the ground.
These tubes release small amounts of water to the plant roots, and lessen evaporation and seepage losses that occur, as the pupils have seen, when sprinkling or flooding techniques of watering are used.

76. Fog catcher,
La Ventana, Guatemala

Glossary

Underlined terms refer to another entry in the glossary.

A

Abiotic: Non-living, referring to an element of an ecosystem. It may be an element such as water, its quality, quantity and distribution in the ecosystem or an element such as soil, its structure and humus content. Ecologists talk of 'abiotic factors', which represent the physical and chemical factors of an ecosystem.

Aerobic bacteria: Living beings, in this case micro-organisms, that need oxygen in order to produce the energy they require for metabolism.

Agroforestry: Method of production combining the cultivation of trees and shrubs with the cultivation of herbaceous species. Agroforestry is recommended to increase the biodiversity of agricultural ecosystems and to improve productivity while reducing land degradation.

Allochthonous: From the Greek *allos* 'foreign' and *chtonos* 'land', literally: land from elsewhere. Allochthonous is the opposite of autochthonous, literally: 'same land'. Allochthonous land or rivers are those which have been carried or diverted from elsewhere, from a foreign region.

Alluvium: All the mineral and organic particles that rivers carry and deposit on their beds or banks, forming a fine deposit of granular particles or what is known as alluvial soil.

Amble: An animal that ambles is one which walks by moving both feet on the same side forward at the same time, such as giraffes, bears, dromedaries and camels.

Angiosperm: From the Greek *aggeion* 'vase or capsule' and *sperma* 'seed'. Angiosperm means a seed in a container, as opposed to gymnosperm (naked seed). Angiosperms are flowering plants, i.e. plants that bear seed-containing fruits. They represent 80% of plant species and more than 200,000 species are known at present. Angiosperms were preceded by gymnosperms in the evolution process.

Animal migration: Migration is the movement of various species over long distances in order to reproduce or escape cold or dry conditions. Animals migrate periodically, returning regularly to their original region. The most spectacular land migrations involve huge numbers of mammals, such as gnus or zebras, which migrate in order to find fresh grass or water by following the rain.

Annual species: An annual plant is one whose life cycle (from germination to death) lasts one year. It therefore has to be regularly re-sown as, for example, with wheat.

Anthropic: From the Greek *anthropos* 'man'. In ecology, this term means any element or factor caused directly or indirectly by human activity and having an impact on the environment: soil erosion, pollution by pesticides, hills created by dykes, and so forth.

Aquifer: A layer of ground or rock that is sufficiently porous (capable of storing water) and permeable (in which water moves freely) to contain an underground water table. The term groundwater is used to describe this type of natural freshwater reservoir, which can be exploited and provide drinking water accessed via wells or water collection systems such as foggaras in dryland regions.

Areism: In hydrology, the term areism is used to describe an area in which there is no organized hydrographic network.

Aromatic plant: Aromatic plants are plants used in cookery and natural medicine for the aromas that they release and the essential oils that can be extracted from them. Examples: star anise or badian, green anise, rosemary, eucalyptus.

Associated: A species is associated with a particular environment insofar as it is dependent on the particular physical and chemical conditions of that environment and on a series of other living species to which it is linked. It may be closely associated with a given environment if the latter is very limited in space and time and has very specific conditions.

B

Biocenosis: From the Greek *bios* 'life' and *koïnos* 'common', 'community'. A community of living organisms (animal, vegetable and micro-organisms) that coexist in a defined space (biotope).

Biodiversity: The variability among living organisms from all sources (plants, animals and micro-organisms) on the earth, the variability within species and the variability among the ecological complexes of which they are part. This includes diversity within species, between species and of ecosystems.

Biosphere reserve: Area consisting of terrestrial, marine or coastal ecosystems, recognized internationally by UNESCO as a priority site for research and the promotion of a balanced relationship between humans and nature. See MAB.

Biotope: From the Greek *bios* 'life' and *topos* 'place'.
A defined natural area characterized by specific geological, soil and climate condi-

tions, of variable size, usually small, that supports animal and plant species that are adapted to these conditions. Examples: ponds, humid grassland, pine forests.

Brackish: Brackish water is less salty than sea water and usually comprises a mixture of sea water and fresh water, as found in lagoons.

Bush: English term used in Australia, New Zealand and South Africa to refer to areas of savannah and forest which are sparcely populated (although the Aborigines live in the Australian bush) or wooded scrubland typical of the Mediterranean region. The bush is characterized by its sparse vegetation and small animal population.

C

Calyx: All the sepals of a flower that form the outer floral envelope. The calyx protects the developing flower bud.

Cambium: Tissue comprising a thin layer of cells found in plant stems and roots. Located between the wood and the bark of trees, it promotes the growth of cells inside and outside (internal and external tissues of the tree).

Camouflage: An instinctive method or system used by an animal to become less visible or to take on an appearance that can deceive another living being. In biology, camouflage is known as mimicry.

Capitulum: Type of inflorescence composed of a set of small sessile flowers (with no tendril, petiole or peduncle) that share the same base, such as members of the daisy family.

Chlorophyll: Chlorophyll is the main assimilating pigment in plants. In photosynthesis, it traps the energy of sunlight, the first stage in the conversion of this energy into chemical energy that is vital for the production of organic carbonaceous matter during photosynthesis.

Cladode: From the Greek *kladôdês* 'branch'. A cladode is a flattened stem, resembling a leaf. The Barbary fig has cladodes, in the shape of tennis rackets, commonly known as 'nopales'.

Class: In biology, class is the third level of traditional classification of living species. The order of carnivores (*Carnivora*), which includes eight families of species (such as cats), belongs to the class of mammals (*Mammalia*).

Cluster: Type of inflorescence comprising a stem with pedunculated flowers growing at different levels.

Cochineal: Small flat insect (*Dactylopius coccus*) that lives on numerous plant species, such as the Barbary fig (*Opuntia ficus-indica*), whose sap it sucks. Cochineals naturally produce a crimson dye. They are collected and dried in order to extract the pigment. See tinctorial.

Commensalism: From the Latin *cum* 'with' and *mensa* 'table', table companion. Commensalism is a relationship between two living beings in which the host provides the 'commensal' with some of its food without receiving any-thing in return. The relationship does not benefit both parties, although the host can still survive and evolve in the presence of the other organism. Certain beetles cohabit with ants in this way.

Compost: Natural fertilizer made from organic plant waste, used to fertilize crops.

Compound leaf: Leaf composed of several laminas known as leaflets. Example: acacia.

Conditions: The abiotic factors of an ecosystem are divided into two categories: resources and conditions. Conditions, in abiotic terms, include temperature, climate, the consequences of global warming and the concept of 'disturbance' linked to fires, severe storms, avalanches, volcanic eruptions and mudslides.

Conservation: The protection of ecosystems, species and natural resources against degradation and destruction so that future generations might benefit from them. The conservation of ecosystems, species and natural resources can result in the planned management of their use by humankind.

Consumer: Within the trophic network, consumers are found at several trophic levels. Primary consumers or herbivorous animals feed on producers; secondary consumers or primary carnivores and parasites feed on herbivorous animals; tertiary consumers feed on primary carnivores. See trophic network.

Convention on Biological Diversity: The Convention on Biological Diversity (CBD) is one of the two conventions signed at the Earth Summit in Rio de Janeiro (Brazil) in 1992; the other was the United Nations Framework Convention on Climate Change. To date, 168 countries have ratified the Convention, which represents a historic undertaking: it is the first global treaty to address all aspects of biological diversity, i.e. not only the protection of species, but also that of ecosystems and the genetic heritage, as well as the sustainable use of natural resources. Finally, the Convention is also the first to recognize that the conservation of biological diversity is "a common concern of humankind" and an integral part of sustainable socio-economic development.

Convergent evolution: When animal or plant species, regardless of their geographical proximity and without common ancestors (i.e. belonging to different families) evolve in a similar way because of similar environmental conditions, the process is known as

'convergent evolution' or 'convergence'. Tuna, sharks and dolphins, which may all live close to each other, show hydrodynamic convergence though only very distantly related.

Corolla: All the petals of a flower, forming the inner floral envelope. When the corolla is spread out, the flower is said to be 'in bloom'.

Contour line: A contour line joins together all points with the same altitude in a particular landscape. A set of contour lines on a map represents the relief. The more tightly packed the contour lines, the steeper the slope. In dryland regions, terraces are built on contour lines, along which stone walls are constructed in order to retain the plots of land.

Cultivar: A cultivar is a plant variety which does not grow in the wild but is produced through cultivation, generally by selection, using horticultural techniques.

Cuticle: The cuticle is a thin layer of cutin, often waxy, like a waterproof varnish, covering the leaves of plants or cactus stems in arid regions. Cutin is a lipid substance designed to prevent water loss, found on the outside of the aerial epidermal cells of plants.

Cyme: A simple inflorescence in which the main stem ends with a flower and the secondary stems are longer than the main stem.

D

Decade of Education for Sustainable Development: In December 2002, the United Nations General Assembly adopted a resolution proclaiming a Decade of Education for Sustainable Development (DESD) from 2005 to 2014. UNESCO was asked to lead the Decade and to develop the conceptual content of Education for Sustainable Development (ESD). In practical terms, this means reviewing and modifying education programmes in order to better integrate the concept of sustainability, interlinking economic, social and environmental objectives as well as respect for cultural diversity and the fight against poverty. See sustainable development.

Decomposer: Term indicating the group of living organisms, including fungi and micro-organisms that live in soil and aquatic biotopes, which break down dead organic matter into mineral compounds.

Defoliator: Defoliation is the phenomenon whereby trees, bushes, sub-shrubs and herbaceous plants shed their leaves. Apart from natural defoliation, it may be caused by fungi, viruses or bacteria, but particularly by defoliating insects which appear cyclically, such as migratory locusts. Swarms of these insects are more likely to affect fragile ecosystems with smaller diversity of species (and predators), such as dryland ecosystems.

Deforestation: All the processes by which humankind is transforming forest ecosystems and causing them to disappear: overuse of wood, forest fires, farming of wooded areas.

Desert varnish (or eolian polish): Dark brown or orange patina coating the surface of sand or rocks in the desert. The presence of metal oxides (iron, manganese) combined with wind action and solar radiation gives mineral particles and rocks this colouring.

Detritivore: Living organism, usually invertebrate, that feeds on dead organic matter from animals or plants (excrement, sloughs, carcasses, plant debris). Ants, iules and necrophages are detritivores. They break down organic matter by digesting or excreting it; it is then easily accessible for bacterial and fungal microflora in the soil. See decomposer.

Dioecious: From the Greek *dis* 'twice' and *oikos* 'house'. This term describes a plant species where the male and female organs are on separate plants; it has male flowers (with stamens) on one plant and female flowers (with pistils) on another. Fructification only takes place if the plants are close enough together. The date palm is a dioecious species.

Distillation: Distillation is a method of demineralizing water and generally considered the most economical way of desalinating sea water on an industrial scale. The basic principle of distillation is simple: since dissolved salts do not turn into vapour under the same conditions as water, the vapour obtained from heating salt water is pure water. Solar distillation is used in dryland areas to desalinate and purify water which is often saline: using exposure to the sun, evaporation and condensation, the water is separated from the salt and purified chemically and bacteriologically.

E

Ecological succession: In ecology, ecological succession represents the development of an ecosystem over time. The process consists of a series of consecutive stages that occur in the appropriate order, such as the clearly distinct stages of pioneer herbaceous vegetation, which rapidly becomes bushy and then shrubby. The transformation of plant and animal communities and of the soil and microclimate that characterize a succession is particularly marked following a major disturbance, such as tree felling or a severe storm.

Ecosystem: An interacting complex of a community of living organisms and its physical, chemical and geographical environment. Thus, air, land, water and living organisms, including human beings, interact to form an ecosystem.

Emergent plant: Plant with roots below water, but most of the plant above the surface, for example, bulrushes (*Juncus sp.*).

Endemic: A species is endemic if it grows in a specific geographical region: it is found in a particular area, the size of which may vary, and its geographical distribution is limited to that area. It is not found anywhere else.

Ephemerophyte: Plant from desert regions that has adapted to the dry conditions by shortening its life cycle. From germination to fructification, the life cycle lasts only 8 to 15 days, or even 1 to 3 days in some cases. The plant needs 4 mm of rainfall to grow.

Erg: An erg is a sandy desert, or more precisely an area of fixed dunes in which the surface sand is constantly reshaped by the wind. Ergs cover around 20% of the total surface of the Sahara. Most are formed in basins by the accumulation of debris transported by wadis. Others result when sand lifted by the wind from hamadas and regs accumulates in depressions and piles up to become dunes. Although the term 'erg' is used in international geographical terminology, the Tuaregs use the word 'edeyen', while in Arabia and Central Asia, the words 'nedouf' and 'koum' are used.

Eolian erosion: The wearing away and transformation of the earth's surface through wind action. A form of surface erosion.
It includes:
Deflation which denotes the lifting and transporting of fine soil particles (small and medium-sized grains of sand, dust);
Corrasion which denotes the mechanical and abrasive effect of particle-laden wind (containing grains of sand and quartz, and ice particles in polar regions) on reliefs and soils.

Erosion: The wearing away and transformation of the earth's surface by water (rain, river, sea), ice or atmospheric agents (wind, heat, precipitations). Thus one refers to water erosion, eolian (wind) erosion and thermal (heat) erosion. This phenomenon is often aggravated by humankind (deforestation, agriculture, road-building) and results in the transformation of the relief and the carrying away of soils.

Estivation: Estivation is a slowed-down state of life among animals, similar to hibernation, in which they fall into a lethargy. Estivation takes place during the hottest periods of the dry season, many animals regulate it themselves, depending on the temperature.

Euphorbia: Herbaceous plant of African origin, common in tropical environments, sometimes arborescent, whose general appearance can resemble that of South American cacti. The euphorbia's strategies for adapting to dry conditions are similar to those of cacti. See succulent plant.

Evaporation: Evaporation is the gradual transformation of a liquid into a gas. In the water cycle, it is the phenomenon through which liquid water escapes into the atmosphere in the form of water vapour without being absorbed by living beings.

Evapotranspiration: Evapotranspiration refers to the accumulation and, more specifically, the total quantity of water transferred from the soil into the atmosphere through evaporation at ground level and plant transpiration.

Evergreen: From the Latin *semper virens* 'always green'. In botany, the term refers to a plant which keeps its leaves all year round, as opposed to deciduous trees. In dryland regions, deciduous trees shed their leaves at the start of the dry season; the drop in soil humidity triggers the fall of the leaves. Trees with persistent or evergreen foliage remain green even during the dry season; examples include the myrtle (*Myrtus communis*), the Phoenician juniper (*Juniperus phoenicea*), the tamarind (*Tamarindus indica*) and the ilex (*Quercus ilex*).

Extinction: The entire disappearance of a species from Earth.

Exudate: The seeping of an organic liquid from an inflamed part of a person's or animal's body. In botany, it is the liquid that seeps from a plant through cracks caused by dryness or wounds (resin, latex, root exudate) and which can be used by human beings (for medicinal or commercial purposes).

F

Family: In biology, the family is the set of genera (or groups of similar species) that share the most similarities. It is the fifth level of traditional classification of living species: kingdom, phylum, class, order, family, genus, species. For example, the genus *Canis*, which includes eight species, including the golden jackal, belongs to the dog family, which comprises 35 species in all.

Fasciculated: From the Latin *fasciculus* 'small bundle'. The term refers to roots that are bundled together, such as the fasciculated roots of wheat.

Fertilization: In botany, in order for a seed to be produced, pollination must be followed by fertilization of the ovules. In pollination, the pollen is carried from the anther (bulging part of the stamen which contains the pollen) to the stigma of the same flower or another flower of the same species. Once it is on the stigma, the grain of pollen sends a pollen tube

down into the ovary to reach an ovule. This pollen tube guides the male gametes to the ovule in order to fertilize it.

Firewood: Wood that is used by the population as the main source of domestic energy: for cooking and light.

Floating plant: Plant without roots, floating freely on the surface of water, such as duckweed.

Fluvial erosion: Fluvial erosion is the degradation and transformation of the landscape caused by rivers. It can happen over the short or long term; for example, the erosion of river banks under the pressure of the current on the outside of bends in a river is different from the water erosion in gullies or gorges that results from long periods of fluvial erosion in areas of sedimentary rock such as canyons in the chalky landscapes of arid regions.

Foggara: Foggaras (an Algerian term) are long underground channels that carry water to some oases from plateaux or rocky massifs. The tunnels intersect the groundwater, from which they take deep-lying water and transport it to the surface near land that needs irrigation. They slope slightly, since the whole system relies on the force of gravity. Vertical wells in the foggaras allow them to be ventilated and cleaned. They were first used in Iran, where they are called 'quanat' and are also found in Morocco, where they are known as 'khettaras'.

Food chain: A series of living beings in which each one eats the one below it in the chain. Since in an ecosystem the links between species are often food-related, these relationships can be represented by sequences in which each individual eats the one below it and is eaten by the one above it. Each link in the chain is a trophic level. See trophic network.

Frugivorous: Phytophages, which are organisms that feed on plants, are divided into several groups, depending on which part of the plant they eat. Frugivorous or carpophagous organisms, for example, eat the fruits or fructifications of plants. They include some types of monkey.

Fungus bed : Place, usually underground, where mushrooms are grown on special layers of earth. Certain ant species grow mushrooms for food in their nests. They cut and chew pieces of leaf in order to make compost and fertilize their fungus beds. These natural fungus beds in turn fertilize the ecosystem.

G

Gabions: From the Italian *gabbione* 'large cage'. This term refers to a sort of container made of solid, interwoven wires and containing stones, used to build retaining walls, for example. Gabions are often used in Africa and South America to combat the effects of erosion. They are placed at an angle or parallel to the river bank in order to combat fluvial or torrential erosion. They also serve to stabilize crumbling slopes and to reduce the impact of runoff.

Genetic make-up: The instructions necessary for the production of the hereditary characteristics of individuals within each species form the genetic make-up of each individual. This genetic information is contained in the nuclei of the cells.

Geophyte: A geophytic plant is a type of perennial plant whose organs enable it to spend the season which is unsuitable for its growth (such as the dry season in arid regions) buried in the ground. The organ in question may be a bulb (onion, lily), a rhizome (Jerusalem artichoke) or one or more tubers (potato).

Germination: Process in which a seed develops, from contact with water until the seedling is formed (young plant with only a few leaves). It only occurs if external conditions are favourable (humidity, temperature, oxygen) and internal conditions are satisfied (viability, dormancy, maturity, effect of light).

Groundwater: Subterranean water reserves, either the result of infiltration of rainwater (renewable) or 'fossil' if it is very old and has been trapped underground since the geological formation of the site (non-renewable). It may be buried more or less deeply in the ground, depending on its origin. Groundwater plays a major role in arid regions, where it forms the majority of water resources.

GTOS TEMS: Global Terrestrial Observing System. GTOS TEMS is a programme of observation, modelling and analysis of terrestrial ecosystems with a view to promoting sustainable development, funded by the United Nations Food and Agriculture Organization (FAO).

Guelta: Usually permanent expanse of water, specific to the mountainous regions of the Sahara, with no visible flow. Usually sunk into the rock, the guelta forms a natural cistern, fed by a spring (of water which gushes out of the rock) or by floods in the rainy season.

Gullying: Gullying is the formation of gullies or ravines; these deep furrows or linear incisions are created by the concentrated runoff of water on a slope. In dryland regions, gullying may be increased by the bareness of the slopes, the absence of vegetation and the impermeability of some soils that experience rainfall that is often brief but intense.

Gymnosperm: From the Greek *gymnos* 'naked' and *sperma* 'seed'. Gymnosperms are plants in which the ovules are naked (not enclosed in an ovary, in contrast to angiosperms). The plant carries its seeds in an open fruit such as cones. All conifers are gymnosperms. There are around 700 species of gymnosperm.

H

Habit: In botany, the habit of a plant is its general shape. The slender shape of the cypress is different from the parasol-like shape of an *Acacia tortilis* or the drooping shape of a weeping cedar with its branches hanging down.

Habitat: A place that is home to a particular plant or animal species, and which provides all that the species requires in order to live.

Halophyte: A halophytic or halophilic plant is a plant that grows in salty soil or which, generally speaking, can tolerate salt.

Hamada: A hamada is a tabular rocky desert, often enclosed by cliffs. Hamadas are particularly common on large plateaux. They are sedimentary and usually chalky. When they are made of sandstone, they are called tassilis, like the *Tassili N'Ajjer* in Algeria. The fields of blocks and large rocks leave little room for the sparse vegetation and, in general, the surface is bare rock, smoothed by erosion.

Heavy metals: The notion of 'heavy metals' has recently been replaced by that of 'metallic trace element', but remains fairly vague. Some authors define heavy metals as the metallic elements between copper and lead in the periodic table, while others consider them to include virtually all metallic elements. Heavy metals such as mercury, lead and cadmium are highly toxic. Traces of all heavy metals are naturally present in the soil, but human activity may have increased the level. The use of some heavy metals is therefore strictly regulated or even prohibited. They should not be thrown away after use, but recycled.

Holistic: From the Greek *holos* 'whole'. The word 'holistic' describes a system of thought in which the characteristics of a being or element can only be appreciated if it is considered and understood in its entirety, in its context and as a whole, rather than when each part of it is studied separately. In ecology, this point of view may be adopted when trying to understand the interactions between the biology of living beings and environmental conditions, or considering human beings as an integral part of the ecosystem.

Huaycos: Huaycos, occurring in South America, are destructive flows of water mixed with mud and stones, following violent rainfall. They flow rapidly down mountainsides, following the channels left behind by the gullying process.

Humus: A complex mixture of organic substances generated by the breakdown of plant (dead leaves) and animal debris by micro-organisms (invertebrates, bacteria, fungi) living in the soil.
Humus is a dark, earthy substance that is present in topsoil and contributes to soil fertility by releasing nitrogen and other nutritive elements vital for plant growth.

I

ICARDA: International Center for Agricultural Research in the Dry Areas. Founded in 1977, ICARDA is one of 15 centres strategically placed throughout the world and funded by the CGIAR (Consultative Group on International Agricultural Research). The main ICARDA research station and headquarters are located in Aleppo, Syria. The centre's task is to improve the welfare of populations and reduce poverty in arid regions of developing countries through research and training, particularly by increasing the production, yield and nutritional value of foods, while preserving and enhancing natural resources.

Indigenous plant (or local plant): A plant that grows naturally in a given geographical area (a portion of the total species range) and whose genetic material has adapted to that location. Where a plant exists only in a single location or region in the world, it is known as an endemic plant (more restrictive).

Infiltration: In hydrology, infiltration means the penetration of surface water into the subsoil through the natural cracks in soil and rocks. It is facilitated by the presence of plants and the flow that takes place at their base. Surface water feeds the groundwater reserves through infiltration and percolation in the soil. See runoff.

Inflorescence: An inflorescence is the arrangement of the flowers on the stem of a flowering plant (angiosperm). There are several kinds of inflorescence, with flowers arranged in different ways: in capitula, clusters, spikes and so forth.

Intercropping: Intercropping means that different crops grown in the same space. Under this system, annual crops and perennial crops are grown together on the same piece of land, as long as they are mutually beneficial and not competitive. This is a way of producing a higher overall yield.

Invasive species: An invasive species is usually one that has been introduced by human beings and has managed to migrate to a region where it has reproduced and spread to such an extent that it competes with native species. It can be very difficult to control and harmful for an ecosystem which does not have any predators or pathogenic agents from its original habitat that are capable of containing it.

IUCN: The World Conservation Union (IUCN) is the world's largest non-governmental organization dedicated to nature conservation. It brings together 83 States, 110 government agencies, more than 800 NGOs and around 10,000 scientific experts in a unique network of partners.

The Union's mission is to influence, encourage and assist societies throughout the world to conserve the integrity and diversity of nature. It also ensures that the use of natural resources is equitable and sustainable.

Iule: Iule is the common name for a myriapod similar to the centipede. Myriapods form a class of articulated animals comprising a head followed by numerous similar segments, each with two pairs of legs.

K

Kesria: In the foggara system, the kesria is a comb-like dividing mechanism (built from the same material, often clay and straw mixed together) which distributes the water between the different plots (and their users) in the oasis.

Khettara: Name used in Morocco for the foggara water system found in Algeria.

Kingdom: The kingdom is the highest level of scientists' classification of living beings. Apart from viruses, living beings are divided into five kingdoms: animals, vegetables, fungi, protists (unicellular eukaryotic organisms) and prokaryotes (such as bacteria).

L

Lagooning: Wastewater purification system in which water is left in the open air in large holding basins. It is purified by the oxidizing and depolluting power of micro-organisms, algae and aquatic plants. The water must be left for a long time.

Lamina: Broad, flat part of a leaf through which the veins pass. Petals and sepals also have laminas.

Leaflet: Part of a compound leaf.

Legume: Plant belonging to the *Fabaceae* family, from the Latin *faba* (bean). It is a very large family with 18,000 species of herbaceous plants, shrubs, trees and creepers, including the groundnut, broom, bean, lupin, pea, acacia and carob. These plants are all able to absorb nitrogen from the air and fix it in the soil thanks to nitrogen-fixing bacteria contained in nodules on their roots. In agriculture and economics, the term specifically refers to species that are cultivated in order to provide food for humans and animals. Here there is a distinction between fodder legumes (clover, alfalfa, sainfoin) and legumes cultivated for their seeds (beans, peas).

Ligneous plant: From the Latin *lignosus, lignum* 'wood'. A ligneous plant is made of wood. A plant may have a ligneous stem rather than a herbaceous one. The term refers to trees, bushes and shrubs, as opposed to herbaceous plants.

Ligule: This term describes tongue-shaped florets (small flowers) that form, for example, the corolla of members of the daisy family.

Litter: In pedology (science of soils), litter is the plant residue (pollen, leaves, fruits, seeds, branches, twigs) that falls to the ground when trees or shrubs shed their leaves (at the start of the dry season in arid regions). It litters the surface soil in forest and bushy areas. Through the activity of micro-fauna (acarids, iules, ants), fungi and bacteria, the litter gradually turns into humus.

M

MAB: The Man and the Biosphere Programme (MAB) is an interdisciplinary project based on research and capacity-building, aimed at improving the relationship of populations with their environment. Launched in the early 1970s, its main mission is to reduce biodiversity loss through ecological, social and economic approaches. It uses its World Network of Biosphere Reserves, comprising 507 sites across the world, as a tool for knowledge-sharing, research and monitoring, education and training, and encouraging participatory management.

Mammal: From the Latin *mamma* 'breast'. Mammals are warm-blooded animals which originally lived on land, though some became adapted to life in the water (whale, sea-lion). Although their shapes, sizes and lifestyles vary tremendously, most animals of this class are covered in hair and they all suckle their young. No other group of animals shares these characteristics. Various examples of mammals: giraffes, bats, monkeys, wallabies, fennecs, dingos.

Medicinal plant: A plant used by humankind for therapeutic purposes.

Mimicry: The ability of some living beings to resemble parts of their environment or other living beings morphologically. The aim of this imitation strategy is to enable the subject to camouflage itself, and avoid being seen by predators, to catch prey or to facilitate relations with fellow creatures. See camouflage.

Monocotyledon: These are angiosperms or flowering plants, the seedlings of which typically have only a single cotyledon or main seed leaf. Examples: wheat, maize, palm tree, iris. They can often be recognized by their leaves, sometimes pinnate, with parallel main veins. Dicotyledons such as the bean, pea, *Rosaceae* or *Asteraceae* plants have two cotyledons.

Monoculture: A form of agriculture consisting of planting a single species over vast areas. Monoculture is a cause of serious ecological imbalances, since it can result in soil erosion and encourages the proliferation of pests and diseases.

Mordant: Substance used in dyeing to prepare the fibre so that the dye can fix to it.

Mutualism or symbiosis: Mutualism is a relationship between two or more living species which benefits both the mutualist and the host. The two species concerned adapt to the relationship and if one changes its behaviour the survival of the other may be jeopardized. For example, the ratel, an African badger, can live in symbiosis with the indicator bird, which guides the ratel to a bees' nest with its song. The ratel opens the nest in order to eat the honey and leaves the wax and larvae for the bird.

N

Native species: A species found naturally in a given geographical location.

Natural resources: Mineral or biological elements for which humankind has found a use. The very concept of a resource implies use. These resources fall into two categories:
- Non-renewable resources, consisting of mineral raw materials, such as metals;
- Renewable resources, that can be used without being exhausted, in that their rate of removal is slower than their rate of renewal, such as forests.

Today, there is a persistent and growing trend towards exhaustion of the world's natural resources.

Nectarivore: Term used in zoology and ornithology to describe an animal that feeds on nectar, a sugary substance, more or less viscous, secreted by flowering plants. Most nectarivores are insects or birds, although some mammals are nectarivorous, including certain bats and a species of opossum. Nectar plays an important role in the pollination of many flowering plants by attracting pollen-gathering insects.

Nitrates: Nitrates are mineral salts of nitric acid. They are nutritious mineral elements for plants, although in areas of intensive agriculture the use of large quantities of nitrate-based fertilizer frequently causes pollution of surface and underground water.

Noria: A noria is a traditional water collection system which brings water up from underground and functions according to the principle of a water-driven chain. It is a large wheel with blades, installed in a river and equipped with a chain that carries a series of trays or buckets that bring the water up. The water then spills into an aqueduct which distributes it.

Nursery: In agriculture, forestry, arboriculture or horticulture, a nursery is a field or plot of land reserved for the reproduction of ligneous plants in particular (trees, shrubs) and other perennial plants, and for cultivating them until they are ready to be transplanted.

Nutrients: A nutritive substance (chemical elements or compounds), either mineral or organic, that is vital to the functioning of all living organisms.
The nutrients that are absorbed by plants for growth are phosphates, nitrates, mineral salts and potassium.

O

Oasis: An oasis is an isolated fertile area in a desert region. It is found near a water source, or where the water table is near the surface, or on dried up riverbeds in the desert. An oasis palm grove is a highly anthropized (see anthropic), irrigated area which is used for intensive agriculture and polyculture.

Omnivore: Living organism which feeds on animals or plants.

Overgrazing: Practice which involves allowing too many cattle to graze for too long a period on land which is unable to regenerate and replenish its plant cover. The term can also refer to the practice of allowing ruminants to graze on land that is unsuitable pasture because of physical features such as a slope. Overgrazing leads to soil erosion and the destruction of plant cover that is already fragile or sparse.

P

Pack saddle: Piece of equipment placed on the back of certain animals to help them carry loads. By extension, 'pack animals' are animals, such as dromedaries or camels, used to carry heavy loads.

Parasitism: Parasitism is a relationship between two living beings from which the parasite benefits at the expense of the host by living either inside or outside it. The parasite is a special kind of predator whose aim is not to kill the host, but to feed off it. However, it is harmful to the host. The tick, for example, is a camel parasite.

Parent bedrock: The parent rock of a soil is its substratum. The concept of parent rock covers everything concerning the nature of rocks that form a geological layer, including their physical and chemical characteristics.

Pedological: From the Greek *pedon* 'soil'. Pedology is one of the main branches of the science of soils, soil formation and soil evolution. It focuses on the interactions between the different phases (liquid, gas, solid) of the soil. It has applications particularly in agriculture, horticulture, forestry and hydrology (water retention by the soil) and in the study of pollution (water filtration).

Percolation: In hydrology, percolation is the phenomenon in which water penetrates and passes through the pores of a soil or rock and slowly moves through the ground. Infiltration and percolation are two consecutive processes that are indispensable for the replenishment of underground water tables by surface water. See runoff.

Perennial species: A perennial plant is one which lives for at least two years (as opposed to annual or biennial plants), and often much longer. Ligneous plants (trees, bushes, shrubs) are, by definition, perennial plants. They may keep their foliage during the winter or rainy season (or the dry season in arid areas), but usually they shed it and survive thanks to their roots or an underground storage organ (bulb, rhizome).

Petiole: The stalk by which a leaf is attached to the rest of the plant.

Phloem: In the structure of a tree, the phloem is the tissue that transports the sap. The sap moves in two directions in the phloem, whereas in the xylem cells the nutritious solution (water and dead cells) moves continuously upwards from the soil.

Phoresy: From the Greek *phoros* 'to carry'. Phoresy is a relationship between two living beings in which one transports the other, usually temporarily. This is a free, non-destructive relationship. Some large rays, for example, carry fish.

Photosynthesis: Bioenergetic process which enables plants to synthesize their organic matter, i.e. to make organic compounds from carbon dioxide, water and mineral salts from the soil using solar energy. By absorbing the sugars produced during photosynthesis, plants produce their vegetable matter, which then serves as food for other living organisms (herbivores). See chlorophyll.

Phyllophagous: A phyllophagous organism is a particular kind of phytophage (all organisms that feed on plants). It feeds specifically on the leaf tissue of plants, either by removing part of it or by sucking the liquid or sap. Cattle are phyllophagous.

Phyllotaxy: Phyllotaxy is the order in which the leaves or branches are attached to the stem of a plant or, by extension, the positioning of the parts of a fruit, flower, bud or capitulum. Phyllotaxy is also the name of the science that studies these arrangements, which are a function of the number of leaves per node and the arrangement of these leaves along the stem. They are called 'alternate' if the leaves are positioned alternately on both sides of the stem, 'opposite' if the leaves are at the same level on the stem, and 'whorled' if there are three or more leaves at each level.

Pistil: A flower's female organs, comprising one or more ovaries, the style(s) and the stigma(s).

Plant cover: Collective vegetation covering the ground.

Pollinating agent: The different factors (forces, organisms) that transport pollen grains from male organs to female organs of flowering plants, enabling fertilization and reproduction of the plants. These factors include the wind, water, insects, birds and some mammals.

Pollination: Process in which a pollen grain from a flowering plant is transported from the stamens (male reproductive organs) to the pistil (female organs) of the same species, making fertilization possible. Some flowers are pollinated by bees or insects, some by birds or certain mammals, and others by the wind. The process of pollination followed by fertilization is the main method of reproduction for flowering plants (angiosperms).

Population growth: An increase in the number of individuals belonging to the same species measured over time. The assessment is often conducted in a single biotope.

Predator: Organism which feeds on other living organisms. Herbivores are predators of plants. In order to feed themselves or their young, some predators use multiple strategies. They directly affect the populations of their prey and help to maintain the biological equilibrium of ecosystems. Super-predators are predators that are not the prey of other predators.

Producer: In a trophic network containing the food chains of an ecosystem, energy passes from food producers to consumers (animals) in a series of stages known as trophic levels, traditionally represented by the successive stages of a pyramid. Producers are plant species that produce proteins and sugars from the light energy of the sun, converting it into molecules that can be used by other organisms.

Propagation: Method of vegetative reproduction involving cutting off a branch of the plant (ligneous or herbaceous) or a leaf (only for certain species such as cacti *Opuntia ficus-indica*) and burying it so that it produces roots and a new individual (perfect clone of the mother plant). Reproduction occurs from this organ or separated part.

Pruning: In forestry, an operation involving cutting the lateral branches of

a tree and sometimes the trunk in order to create new shoots from which the wood is used.

Puisard: French term to qualify a honad dug shallow well. Puisards exist in the Saharan region. The water it provides is not very deep and a shepherd can extract it without any special technique or equipment. A puisard can be dug with a bowl in a few hours. Deeper wells can be dug in the surface of a dried up pond. They are abandoned after use, and quickly dry up.

Purification: Water purification or decontamination is the process of purifying waste water from homes, agriculture or industry before it is returned to the natural environment. Purification is becoming increasingly necessary in order to prevent environmental pollution and land degradation. See lagooning.

Q

Quanat: Name given in Iran to the water collection system known as foggaras in Algeria.

R

Radicle: A radicle is a small secondary root. Found in large quantities, they draw up water and nutrients from the soil and are composed of many absorbent hairs.

Refractive index: The refractive index refers to the change of direction of light when it passes from one environment to another, such as from air to water or glass. The index value depends on the wavelength of the ray of light. It varies because visible white light is made up of several 'colours' whose wavelengths differ because the angle of refraction is different for each colour.

Reg: A reg is a stony desert, a large flat expanse of rocky ground with very little vegetation. Regs result from rock disintegration, mechanical crumbling or deflation caused by the wind. The stones are often covered by desert varnish or eolian polish.

Resources: The abiotic factors of an ecosystem are divided into two categories: resources and conditions. Resources, in abiotic terms, include water, carbon dioxide, light, soil nutrients and space.

Rhizome: Underground stem of certain perennial plants, usually horizontal and containing no chlorophyll. A rhizome has small leaves in the form of flakes, nodes and buds which produce aerial stems and roots. As it branches out, the rhizome facilitates vegetative reproduction of the plant, which can proliferate in this way (e.g. bamboo). Some thick rhizomes, such as ginger, are edible, while others develop into edible tubers, like the yam.

Runoff: In hydrology, runoff is the flow of water on the ground's surface, in contrast to infiltration. Rainwater flows down slopes in the landscape and is one of the causes of erosion. The water erodes the land over which it flows by carrying away soil particles whose size depends on the quantity of water and the steepness of the slope.

S

Sacred natural site: Traditional societies all over the world have given a particular status to certain natural sites that they consider sacred: these show the diversity of traditional belief systems which exist in various forms. Whether sacred forests, mountains, springs, rivers, lakes or caves, or the many other kinds of venerated sites and places, their spiritual dimension endows them all with a sense of meaning and importance. In essence, these were the world's first protected sites.

Sebkha: Sebkhas are temporary salt marshes in the desert. The water may come from runoff or temporary sources.

Sediments: Material resulting primarily from rock erosion (soil, sand, clay, gravel, blocks), that is transported by various agents, such as water, wind, ice and gravity, and which, once set down, becomes compressed and forms a rock. It may also originate from organic matter (shell or coral debris accumulation).

Seguia: Once it has emerged from the ground, the water from foggaras moves through the oasis: it is drained into open-air channels, seguias, which distribute it to different areas.

Seed dispersal: It is by means of seed dispersal that plants scatter themselves through their environment. Seeds may be dispersed by the wind, water or animals (birds, insects, etc.). This phenomenon is very useful from an ecological point of view because it enables seeds to reach habitats suitable for the growth of future plants. More generally, it reduces competition between individual plants by spreading them across a wider area; it facilitates genetic exchanges and it helps to create new populations.

Simple: Leaf whose lamina is a single piece, not compound. Example: the leaf of a fig or olive tree.

Species: Group of interfertile populations, isolated from other such groups from a reproductive point of view and defined by a unique combination of characteristics.

Spike: Type of inflorescence in which the flowers or spikelets (grasses) are attached to a main stem without a peduncle.

Spontaneous vegetation: Vegetation unassisted by human efforts undergoes a spontaneous slow transformation during which different plant groups succeed one another in various locations. These populations are known as 'spontaneous vegetation'. It is affected by human activity and maintained by various forms of exploitation, although it evolves independently, is rarely disturbed and is often very diverse.

Stamens: Male sexual organs of a flower, the bulging end parts of which (anthers) contain the pollen (pollen sacs).

Stolon: Thin aerial stem that creeps along the surface of the ground, aiding vegetative reproduction of a plant. At a node, often in contact with the soil, the stolon produces a new plant by taking root at its far end. The stolon dies and disappears when the new plant becomes independent.

Stomata: A stomata is a tiny pore in the epidermis of the aerial organs of plants (usually on the under side of the leaves). It controls the passage of gases between the plant and the air (carbon dioxide, oxygen, water vapour). There can be between 50 and 500 stomata per mm? on a leaf, although in arid areas there are much fewer in xerophytic species, where they are often buried in the epidermis, at the bottom of grooves in the leaf. Through the stomata, the plant controls its own internal flow of water and nutritious substances. For example, when it is too hot or there is insufficient water, the stomata can close and block the photosynthesis and transpiration processes.

Substratum: In geology, the substratum lies underneath a geological layer. This geological substratum gives the soil its original mineral composition. See parent rock.

Succulent plant: From the Latin *succulentus* 'full of juice'. Succulent plants are fleshy plants that can survive in arid environments with the characteristics of the soil and climate specific to these regions. They can survive because of their ability to store water in their leaves, stems and roots. Examples: agaves, euphorbia, aloe, cacti.

Sustainable development: In 1987, sustainable development was defined by the World Commission on Environment and Development as "meeting the needs of the present without compromising the ability of future generations to meet their own needs". The definition has been refined over the years and sustainable development can be described as a form of development that respects the environment and makes wise use – through rational, moderate exploitation – of nature and its resources, thus ensuring the indefinite maintenance of biological productivity in the biosphere. *Agenda 21*, a global action plan adopted by 173 countries during the 1992 Earth Summit in Rio de Janeiro, set out a whole series of principles designed to help governments and authorities to implement policies based on sustainable development. Today, *Agenda 21* remains the touchstone for the implementation of sustainable development in a given territory.

SUMAMAD (Sustainable Management of Marginal Drylands): SUMAMAD is a project of UNESCO's Man and the Biosphere Programme (MAB) which aims to strengthen the sustainable management of marginal drylands in northern Africa and Asia. The project proposes management methods which promote economic sustainability and the conservation of resources, particularly soils and water reserves, and which foster the rehabilitation of degraded lands using an approach based on the participation of local communities. Training, capacity-building and interaction with landowners, farmers and other stakeholders is a key aspect of the project, which combines sustainable traditional management practices with scientific expertise.

T

Tannins: Substances of organic origin found in all parts (bark, roots, leaves) of most plants, characterized by their astringency (feeling of dryness in the mouth) and used to make wine, tan animal skins, protect leather and dye fabrics. The bark of *Acacia seyal* is rich in tannins used for red dye. See tinctorial.

Taproot: A taproot is the main root of a plant, which buries itself vertically in the ground and is dominant vis-à-vis the secondary roots.

Tinctorial: Used for dyeing. Plants and substances (mineral pigments) are described as 'tinctorial' if they provide a substance used for dyeing and decorating textiles, leather, ceramics, walls, bodies... or the preparation of food colourings.

Transpiration: There is a difference between animal persiration and plant transpiration. Animal transpiration is the elimination of sweat through the skin pores of humans and mammals; it helps to regulate body temperature. Plant persiration is the elimination of excess water vapour from plants. It is a continuous process which involves both the evaporation of water through the leaves and the simultaneous absorption of water by the roots in the soil. Trans-

piration takes place through the stomata and stimulates the movement of sap.

Transplant: To dig up a herbaceous plant or tree (generally a seedling) and replant it elsewhere.

Trophic network: This refers to all the food chains linked together within an ecosystem. These food chains link the various ecological categories of living beings that make up the biocenosis: *producers*, which are green plants that constitute the first trophic level; *primary consumers*, which are herbivorous animals and represent the second trophic level; *secondary consumers*, which are mainly carnivores and parasites that feed on herbivores and constitute the third trophic level; and *tertiary consumers*, which feed on carnivores and represent the fourth trophic level. We should not forget *decomposers*, which break up and mineralize dead organic matter. *Cf. diagram on p.21.*

Tubular: Tubular or tubulous. Refers to tube-shaped florets (small flowers) that form the heart of the flowers of the daisy family.

Tumulus: A tumulus is an artificial mound, sometimes circular, covering a burial place. Earth tumuli are rare these days, although stone tumuli (or cairns) are fairly well preserved. Civilizations in pre-Colombian America and Ancient Egypt built tumuli.

Turbidity: Turbidity is the cloudiness of a liquid, usually water. It is the result of suspended particles which absorb, diffuse or reflect light. Turbidity is an important ecological factor which can indicate a high level of sediments, high plankton content or water pollution.

U

Underflow: Flow occurring beneath a river bed, in the mass of its permeable alluvial deposits.

UNESCO (United Nations Educational, Scientific and Cultural Organization): UNESCO's ecology-related scientific programmes place ecological and earth sciences at the service of sustainable development. Among other things, these programmes contribute to the combat against desertification. The Man and the Biosphere Programme (MAB) is responsible for most of the activities relating to biodiversity. The International Hydrological Programme (IHP) deals with the key issue of water resources and ecosystems by trying to reduce threats to water systems. Most of the research in the fields of geology and geophysics is conducted under the auspices of the International Geoscience Programme (IGCP).

UNESCO Associated Schools Project Network: Created in 1953, the UNESCO Associated Schools Project Network or ASPnet is a global network of around 8,000 educational institutions in 177 countries (ranging from nursery schools to primary and secondary schools and teacher training institutions) which work in support of quality education.

Ungulates: From the Latin *ungula* 'nail'. Ungulates form a group of mammals which have one or more hooves at the end of their limbs. A hoof is a highly developed horny formation (like the nails of primates) that protects the animal's toes as it walks. The gazelle is an ungulate.

United Nations Convention to Combat Desertification (UNCCD): International agreement adopted in 1994 in Paris. 191 countries have ratified the Convention to date (2005). It aims to combat desertification and mitigate the effects of drought in countries experiencing serious drought and/or desertification. The action programmes of the Convention are designed to improve land productivity, restore (or conserve) soils, define the best use of water and achieve sustainable development in affected regions.

V

Vegetative reproduction: Vegetative reproduction is a type of asexual reproduction. Unlike seeds, which produce new specimens (with a new genetic endowment), vegetative reproduction produces clones (individuals genetically identical to the mother plants). It takes place spontaneously or can be provoked, without the involvement of the seed, by means of cuttings (propagation), grafts or stolons. Vegetative reproduction is therefore distinct from generative or sexual reproduction, which requires a seed.

W

Wadi: From the Arabic *wadi* 'river'. Temporary river with a very irregular hydrological regime in semi-arid Saharan regions. They are dry most of the time but can flood violently, particularly in mountainous areas, carrying huge quantities of mud.

Windbreak: Barrier, often built using branches or palms, to combat the action of the wind and hold back sand dunes or protect crops.

X

Xerophyte: Xerophytes are plants that are adapted to dry environments. They are found in various environments such as rocky deserts or bushy areas typical of arid or semi-arid regions. They are particularly good at combating water loss and water stress and getting as much water as their environment can provide. Morphological adaptations of xerophytes include the thick, hard surfaces of plants such as *Opuntia*, from the cacti family, which are covered in a waxy cuticle (a waterproof layer resembling varnish) that restricts transpiration. Another example is the deep root system of acacias, designed to reach the most inaccessible underground water reserves. See succulent plant and euphorbia.

Xylem: In the structure of a tree, xylem is tissue that can transport large quantities of water from the nutritious soil to the leaves which carry out photosynthesis. It therefore conducts a solution containing water and mineral salts to the top of the tree and to the leaves, which act as pumps.

Xylophagous: From the Greek *xylon* 'wood'. Describes animals which eat wood and which, either as larvae or as adults, eat the branches, trunks or roots of dead or living trees.

Z

Zaï: In Africa, zaï is a traditional soil preparation technique which involves making holes in the ground to catch a small amount of runoff and then sowing millet or sorghum seeds in the holes. The resulting seedlings will then be less affected in the case of irregular rainfall. The technique is more effective if the ground is prepared very early, well before the rain arrives: organic waste is placed in the holes and is eaten by termites which have tunnelled through, thus increasing water infiltration; the seeds can then be sown and manure added.

Zoochory: Zoochory is the process through which plant seeds are dispersed (seed dispersal) by animals. The seeds may be dispersed in animal faeces (endozoochory) or externally, via hooks or thorns on the fruit which attach themselves to the animal's fur (epizoochory).

Zooplankton: Part of the biomass that forms the plankton in marine environments or in fresh or brackish water in dryland regions, zooplankton is an animal plankton comprising various small animal organisms that live in suspension in water, usually protozoa, coelenterates and crustaceans in their larva or adult stage. Zooplankton is very important in food chains, in biochemical cycles (carbon cycle) and in water decontamination systems (lagooning).

Plant prints made by children during a painting workshop
© Hélène Gille

Acknowledgements

We are particularly grateful to the following people for their contribution to the teaching resource kit: Jean-Pierre Ablard, Neal Cooper, Nina Cooper, Ecole Perceval of Chatou, Rogo Koffi Fiangor, Cathy Lee, Catherine Kilbane, Frédéric Létang, Ana Persic and photographers Yann Arthus-Bertrand, Olivier Brestin, Michel Le Berre.

A Creative Approach to Environmental Education

This teacher's manual, published by UNESCO, forms part of the teaching resource kit entitled: *A Creative Approach to Environmental Education/Teaching Resource Kit for Dryland Countries.*

The kit is available in four languages (Arabic, English, French and Spanish) and comprises three documents:

- A teacher's manual, the central component of the kit, divided into three chapters,
- A class notebook for pupils,
- A map of the world's drylands.

United Nations
Educational, Scientific and
Cultural Organization

Man and the Biosphere
Programme

School _____

Country / town _____

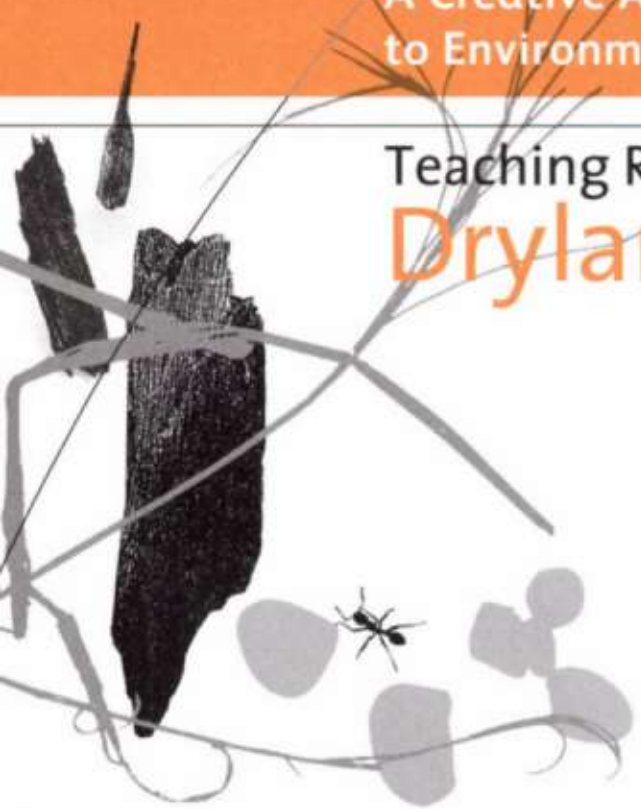
Class _____

Teacher's name _____

The class notebook

A Creative Approach to Environmental Education

Teaching Resource Kit for Dryland Countries



United Nations Educational, Scientific and Cultural Organization

Man and the Biosphere Programme

UNESCO Associated Schools

UN Decade of Education for Sustainable Development 2005-2014

IYDD International Year of Deserts & Desertification 2006

Teaching Resource Kit for Dryland Countries

A Creative Approach to Environmental Education

Officer-in-charge:
Thomas Schaaf, UNESCO

Editor and project designer:
Hélène Gille

Scientific advisers:
Michel Le Berre, Thomas Schaaf

Coordination and iconography:
Hélène Gille
With the collaboration of:
Cathy Lee

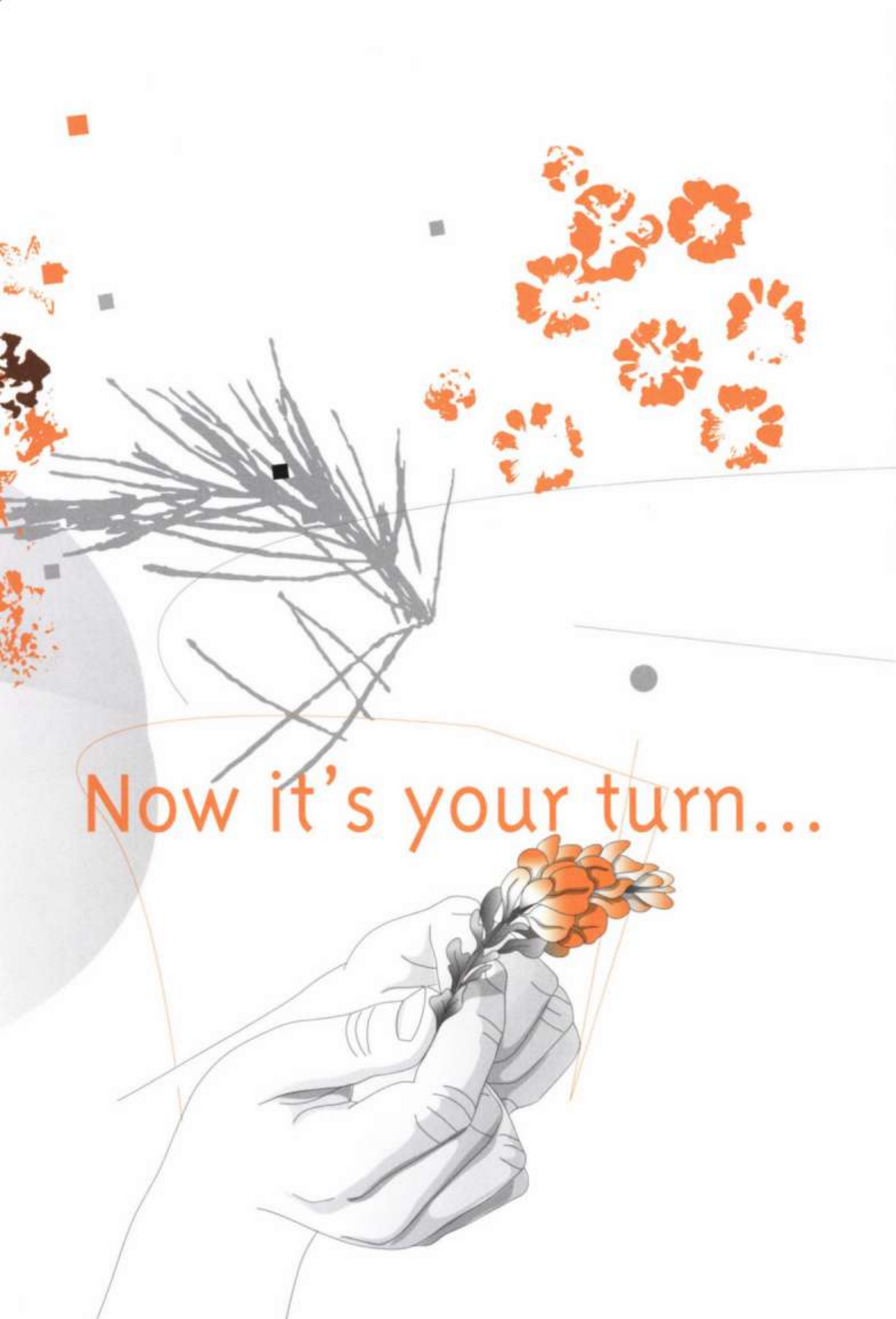
Graphic design:
Mecano, Laurent Batard
assisted by Marion Malpeyrat
and Claire Morel Fatio

Administrative assistance:
Natasha Lazic

Printing:
LM Graphie

Printed on Centaure blanc
300g and 120g

Published in 2008 by
the Man and the Biosphere Programme (MAB), UNESCO
1, rue Miollis
75732 Paris Cedex 15, France
Email: mab@unesco.org
www.unesco.org/mab


Now it's your turn...

Talk about the activity

Why the class notebook ?

You have just completed one of the kit's activities, so... get your pencils ready!
Here is a notebook especially for you, which will follow the teacher's manual.

Inside the notebook you will find the double page that corresponds to the activity you have just completed. It's now your turn to fill it in...
With help from your teacher, get together in groups and, as you carry out the activities, each group takes it in turns to fill in the corresponding double page.

Try to remember the exercise you did, get back into the mood...
What were the different stages of the activity? What were the objectives?
Which images, which scene sticks in your memory?
Is there one step in the activity that you particularly liked?
Describe this... in your own words and with the terms you have learnt.
Answer the questions, and don't forget to draw and add colour.

Which object, element or detail marked you most while you were doing the activity together? How can you represent it?
Practise... and try to sketch it. What matters is to keep a record.

If you happen to need more space, you can use the last pages in the notebook reserved for extra notes and drawings (see pages 44 to 48).

Once the notebook is full, ask your teacher to make a photocopy and, if the whole class agrees, you can send a copy of the notebook to another partner school in UNESCO's Associated Schools Network (ASPnet).
With help from your teacher, you can enquire about member schools of the network by contacting your national coordinator through the UNESCO office in your country or from the Internet webpage about the programme: **http://www.unesco.org/education/asp**.
In this way, you can exchange your notebook with another associated school and compare your notes, discoveries and the ecosystems in your respective regions!

get ready with your pencils

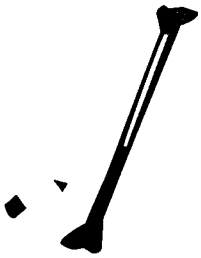
Chapter n°1 | Activity n°1

Collecting Treasures

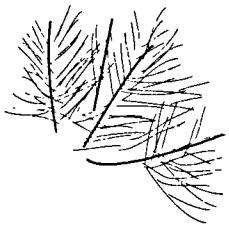
Where and when did you carry out the activity?

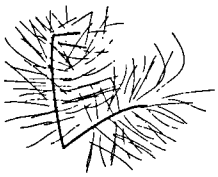
How did it take place?

Explain in more detail:



What is a biotope?





While carrying out the activity, which element (or object) left the biggest impression on you?

Can you describe it? draw it? paint it?

Stick photos that you may have taken during the exercise...

get ready with your pencils

Chapter n°1 | Activity n°2

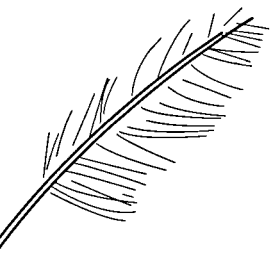
Composing Shapes on the Ground

Where and when did you carry out the activity?

How did it take place?

Explain in more detail:

Why do species depend on their environment and other species to live?



While carrying out the activity, which element (or object) left the biggest impression on you?

Can you describe it? draw it? paint it?

Stick photos that you may have taken during the exercise...

get ready with your pencils

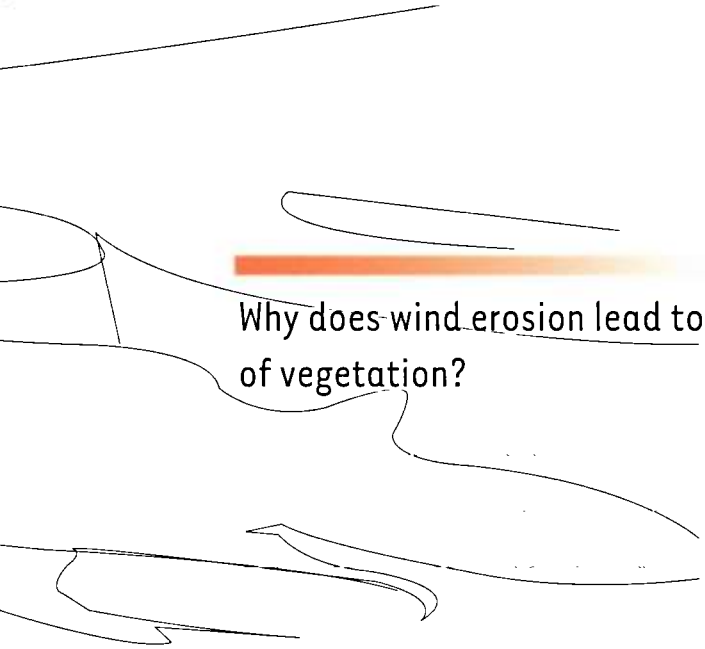
Chapter n°1 | Activity n°3

Land, Rock and Erosion

Where and when did you carry out the activity?

How did it take place?

Explain in more detail:



Why does wind erosion lead to degradation of soils that are bare of vegetation?

While carrying out the activity, which element (or object) left the biggest impression on you?

Can you describe it? draw it? paint it?

Stick photos that you may have taken during the exercise...

→ → →

get ready with your pencils

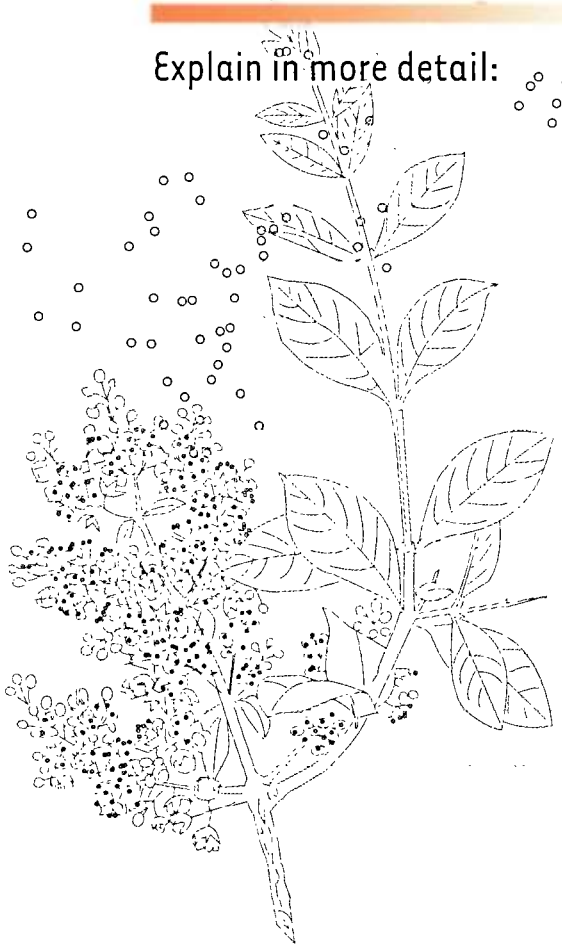
Chapter n°1 | Activity n°4

Nature's Palette

Where and when did you carry out the activity?

How did it take place?

Explain in more detail:



What are the natural dyes (plant and mineral) used by the population for dyeing and painting (textiles, leather, wood, ceramics, walls, body paints)?

While carrying out the activity, which element (or object) left the biggest impression on you?
Can you describe it? draw it? paint it?
Stick photos that you may have taken during the exercise...

get ready with your pencils

Chapter n°1 | Activity n°5

On the Tracks of Wild Animals

Where and when did you carry out the activity?

How did it take place?

Explain in more detail:

What kind of information can we gather about the diverse behaviour of animal species obtained from tracks and various other traces left by animals?

While carrying out the activity, which element (or object) left the biggest impression on you?

Can you describe it? draw it? paint it?

Stick photos that you may have taken during the exercise...

get ready with your pencils

Chapter n°1 | Activity n°6

Mural of an Ecosystem

Where and when did you carry out the activity?

How did it take place?

Explain in more detail:

Which species act as producers, consumers and decomposers of a trophic network or food web that you have studied to understand the local ecosystem? (see figure on page 21 in the teacher's manual)

While carrying out the activity, which element (or object) left the biggest impression on you?

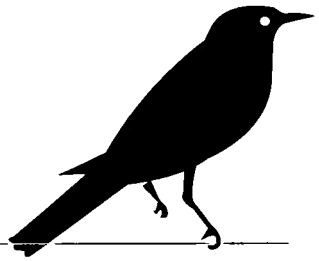
Can you describe it? draw it? paint it?

Stick photos that you may have taken during the exercise...

get ready with your pencils

Chapter n°1 | Activity n°7

Biodiversity Playlets: Links in the Web of Life



Where and when did you carry out the activity?

How did it take place?

Explain in more detail:

Can you name other examples of agricultural practices that lead to the loss of biodiversity in drylands ecosystems?

While carrying out the activity, which element (or object) left the biggest impression on you?
Can you describe it? draw it? paint it?
Stick photos that you may have taken during the exercise...

get ready with your pencils

Chapter n°2 | Activity n°1

Steps towards Understanding Plants and Flowers

Where and when did you carry out the activity?

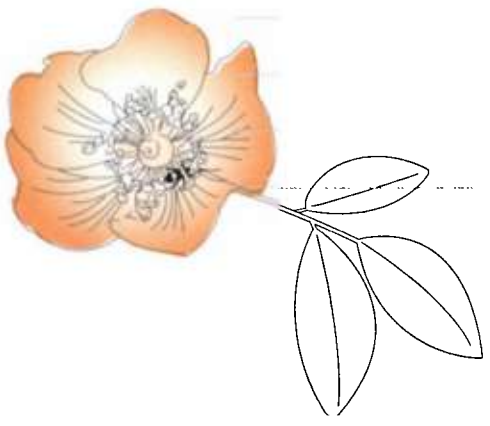
How did it take place?

Explain in more detail:

Among the flowers that you find around you, can you name three different examples of inflorescences, can you describe and colour them?
How are these flowers pollinated?

While carrying out the activity, which element (or object) left the biggest impression on you?
Can you describe it? draw it? paint it?

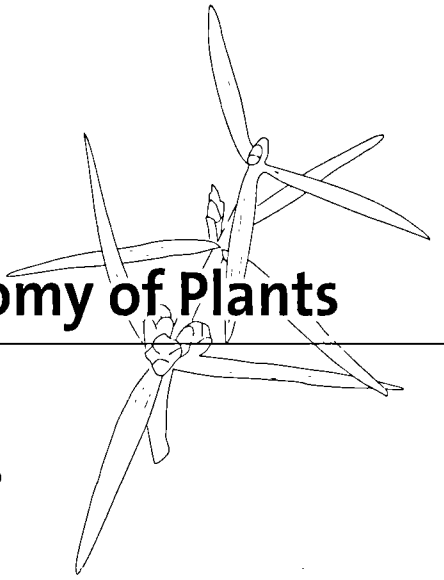
Stick photos that you may have taken during the exercise...



get ready with your pencils

Chapter n°2 | Activity n°2

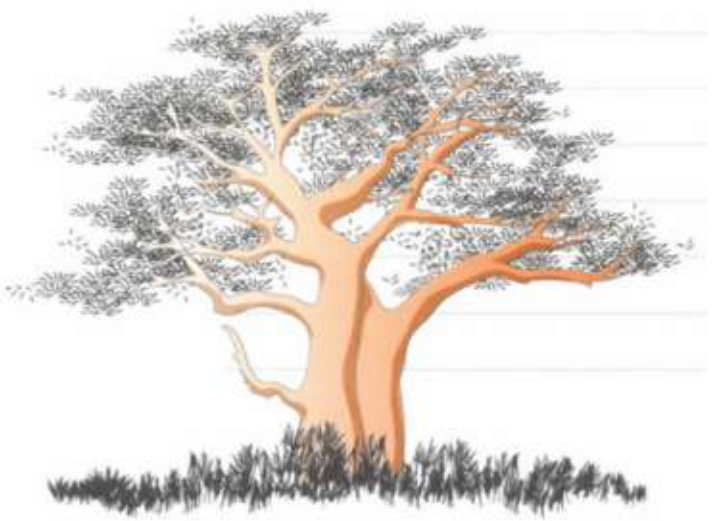
Form and Design: the Anatomy of Plants



Where and when did you carry out the activity?

How did it take place?

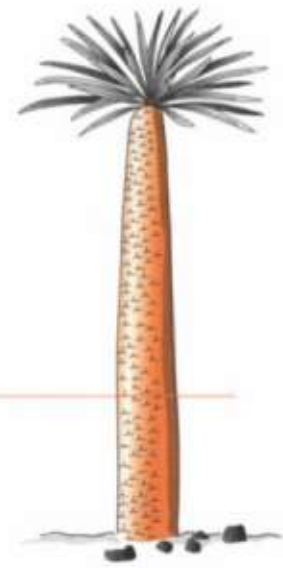
Explain in more detail:



What are the external factors that can cause a tree to adopt an irregular shape and divert it from its natural growth?

While carrying out the activity, which element (or object) left the biggest impression on you?
Can you describe it? draw it? paint it?
Stick photos that you may have taken during the exercise...

get ready with your pencils



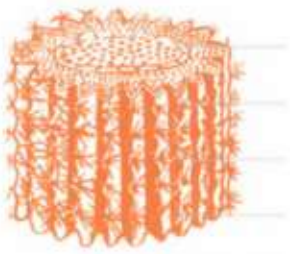
Chapter n°2 | Activity n°3

Dryland Living: How Plants Adapt to Deserts

Where and when did you carry out the activity?

How did it take place?

Explain in more detail:

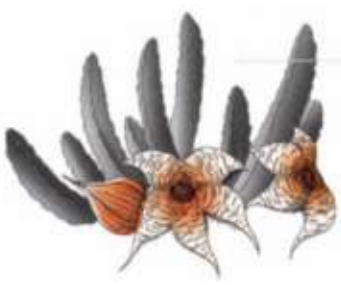


What are the main morphological adaptations used by xerophytes to obtain water on the one hand and reduce water losses by transpiration on the other hand?

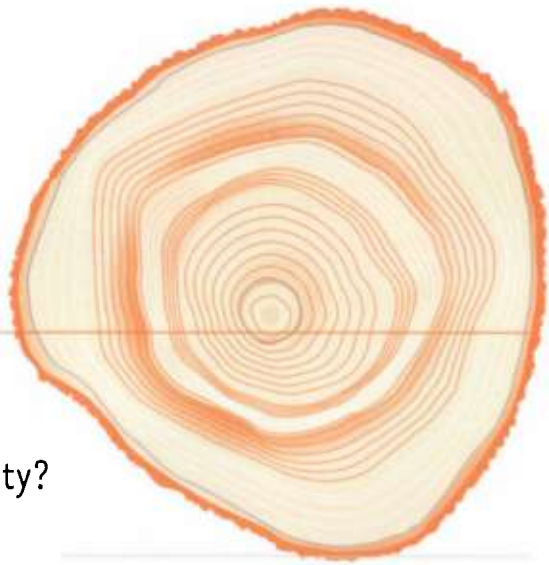
While carrying out the activity, which element (or object) left the biggest impression on you?

Can you describe it? draw it? paint it?

Stick photos that you may have taken during the exercise...



get ready with your pencils



Chapter n°2 | Activity n°4

The Tree as Ecosystem

Where and when did you carry out the activity?

How did it take place?

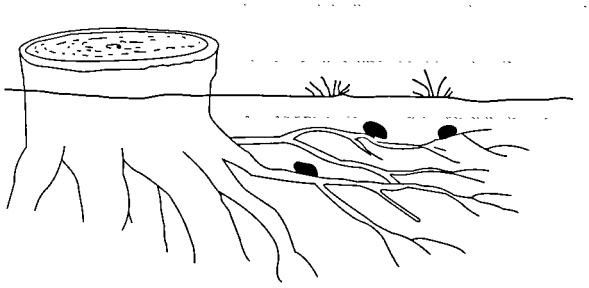
Explain in more detail:

What is the purpose of tree roots and what is the specific role of radicles?

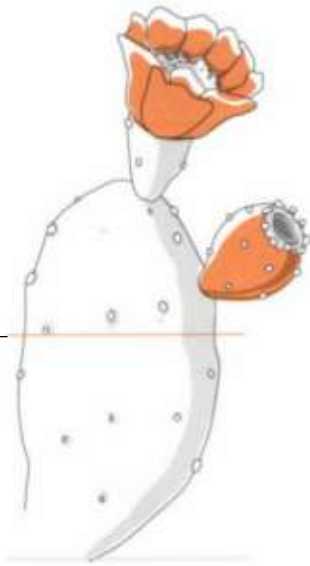
While carrying out the activity, which element (or object) left the biggest impression on you?

Can you describe it? draw it? paint it?

Stick photos that you may have taken during the exercise...



get ready with your pencils



Chapter n°2 | Activity n°5

An Inventory of Useful Plants

Where and when did you carry out the activity?

How did it take place?

Explain in more detail:

Did you identify a plant species that is at the same time edible, medicinal and used in the construction of dwellings?
What is it called and can you describe its uses in detail?

While carrying out the activity, which element (or object) left the biggest impression on you?
Can you describe it? draw it? paint it?
Stick photos that you may have taken during the exercise...

get ready with your pencils

Chapter n°2 | Activity n°6

The Plant as Mascot

Where and when did you carry out the activity?

How did it take place?

Explain in more detail:

Under what circumstances can a plant species, which is particularly useful to the population, be unable to regenerate in the ecosystem?

While carrying out the activity, which element (or object) left the biggest impression on you?
Can you describe it? draw it? paint it?
Stick photos that you may have taken during the exercise...

get ready with your pencils

Chapter n°2 | Activity n°7

The Experimental Garden

Where and when did you carry out the activity?

How did it take place?

Explain in more detail:

What conclusions do you draw from your practical experiments on garden vegetation, from the plantation exercises in the nursery and from the transplantation, sowing and cutting exercises?

While carrying out the activity, which element (or object) left the biggest impression on you?
Can you describe it? draw it? paint it?
Stick photos that you may have taken during the exercise...

get ready with your pencils

Chapter n°3 | Activity n°1

Poem: Water, Source of Life

Where and when did you carry out the activity?

How did it take place?

Explain in more detail:

What images of water exemplify its refreshing, fertilizing and purifying qualities? Can you describe and draw them?

While carrying out the activity, which element (or object) left the biggest impression on you?
Can you describe it? draw it? paint it?
Stick photos that you may have taken during the exercise...

get ready with your pencils

Chapter n°3 | Activity n°2

Paint, Liquidity, Transparency: Water and the Senses

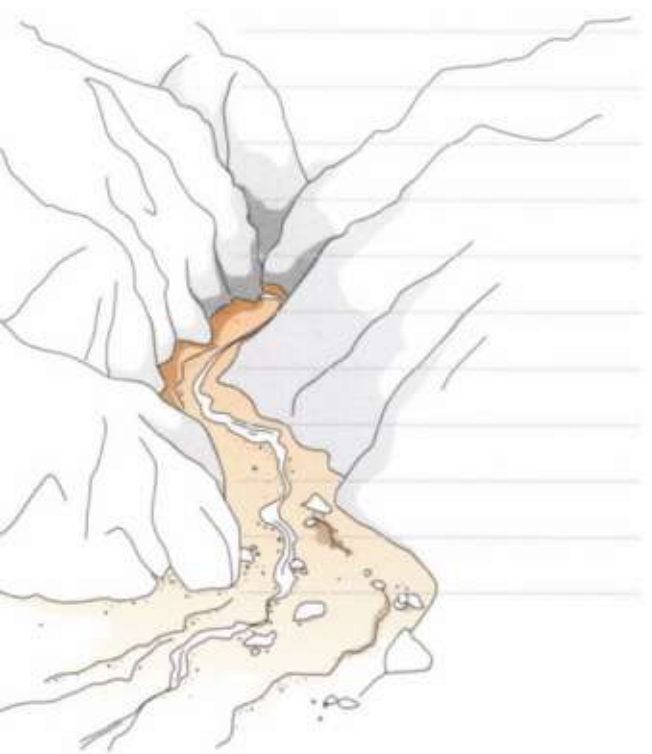
Where and when did you carry out the activity?

How did it take place?

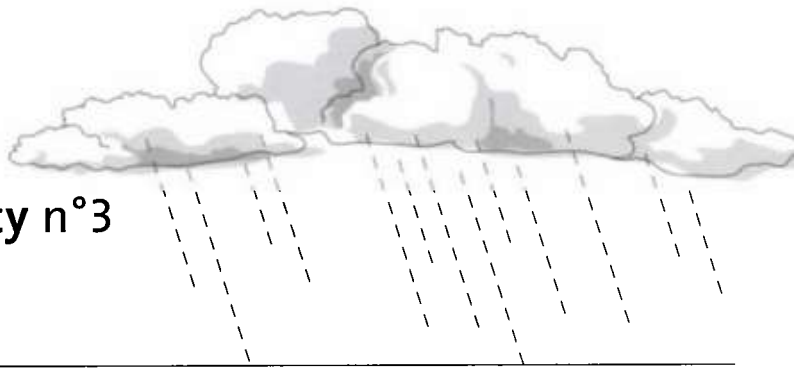
Explain in more detail:

What are the traces left by water – resulting from its fluidity, its mobility, and its erosive action – in nature?

While carrying out the activity, which element (or object) left the biggest impression on you?
Can you describe it? draw it? paint it?
Stick photos that you may have taken during the exercise...



get ready with your pencils



Chapter n°3 | Activity n°3

The Water Cycle

Where and when did you carry out the activity?

How did it take place?

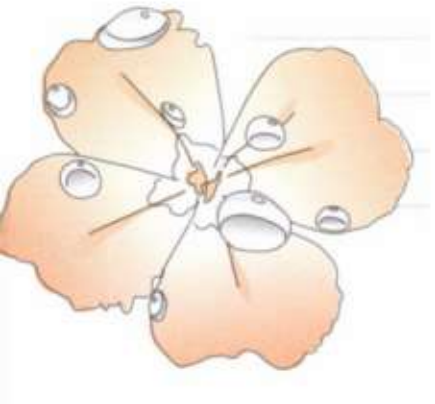
Explain in more detail:

Can you describe the successive stages of the water cycle?

While carrying out the activity, which element (or object) left the biggest impression on you?

Can you describe it? draw it? paint it?

Stick photos that you may have taken during the exercise...



get ready with your pencils

Chapter n°3 | Activity n°4

Diary of a Watering Place

Where and when did you carry out the activity?

How did it take place?

Explain in more detail:

Can you specify and draw examples of the ecological and utilitarian functions of surface watering places (pond, guelta, torrent) that you are familiar with in your surroundings?

While carrying out the activity, which element (or object) left the biggest impression on you?
Can you describe it? draw it? paint it?
Stick photos that you may have taken during the exercise...

get ready with your pencils

Chapter n°3 | Activity n°5

Clean Water for the Village: Map and Strip Cartoon

Where and when did you carry out the activity?

How did it take place?

Explain in more detail:

What types of behaviour on the part of the population can we qualify as inappropriate or harmful to the management and maintenance of water natural resources?

While carrying out the activity, which element (or object) left the biggest impression on you?
Can you describe it? draw it? paint it?
Stick photos that you may have taken during the exercise...

get ready with your pencils

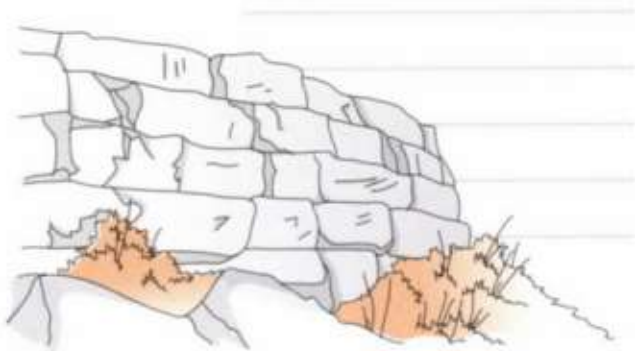
Chapter n°3 | Activity n°6

Panelled Fresco of the Village Water Management System

Where and when did you carry out the activity?

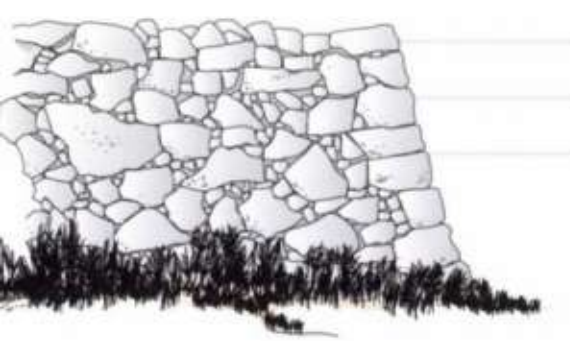
How did it take place?

Explain in more detail:



What did you particularly enjoy in rediscovering the traditional techniques for the harvesting, collecting and transporting of surface and underground water?

While carrying out the activity, which element (or object) left the biggest impression on you?
Can you describe it? draw it? paint it?
Stick photos that you may have taken during the exercise...



Notes and sketches

Notes and sketches

Notes and sketches

Notes and sketches

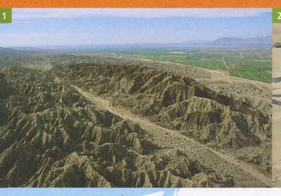
Notes and sketches

Names of the class pupils

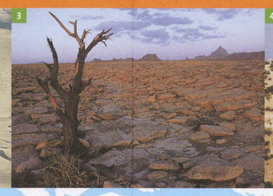
United Nations
Educational, Scientific and
Cultural Organization

Man and the Biosphere
Programme

Kit pédagogique pour les pays situés en zones sèches / Teaching resource kit for dryland countries / Material educativo para los países situados en zonas secas / أدوات تعليمية لبلدان الأراضي الجافة


1

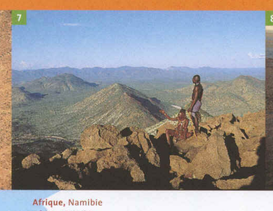

2

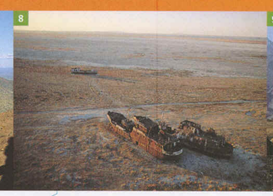

3

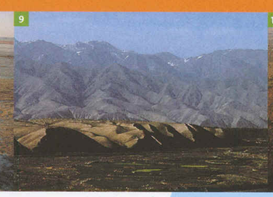

4

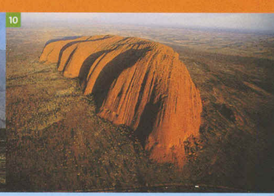

5


6


7


8


9


10

Amérique du Nord, États-Unis d'Amérique
North America, United States of America
América del Norte, Estados Unidos de América
© Yann Arthus-Bertrand *La Terre vue du Ciel* / UNESCO

Amérique du Sud, Pérou
South America, Peru
América del Sur, Perú
© Yann Arthus-Bertrand *La Terre vue du Ciel* / UNESCO

Amérique du Sud, Chili
South America, Chile
América del Sur, Chile
© Gilles Santantonio

Europe, Espagne
Europe, Spain
Europa, España
© Asociación española agricultura de conservación

Afrique, Tunisie
Africa, Tunisia
África, Túnez
© Yann Arthus-Bertrand *La Terre vue du Ciel* / UNESCO

Afrique, Mali
Africa, Mali
África, Mali
© Yann Arthus-Bertrand *La Terre vue du Ciel* / UNESCO

Afrique, Namibie
Africa, Namibia
África, Namibia
© Yann Arthus-Bertrand *La Terre vue du Ciel* / UNESCO

Asie, Kazakhstan
Asia, Kazakhstan
Asia, Kazajstán
© Yann Arthus-Bertrand *La Terre vue du Ciel* / UNESCO

Asie, Chine
Asia, China
Asia, China
© Yazid Tizi

Australie
Australia
Australia
© Yann Arthus-Bertrand *La Terre vue du Ciel* / UNESCO

Hyper aride Hyper arid Hiperárido
Aride Arid Árido
Semi-aride Semi-arid Semiárido
Subhumide sec Dry Subhumid Seco subhúmedo
Humide Humid Húmedo
Climat froid Cold climate Clima frío

Vents desséchants Desiccating winds Vientos secos

équateur / equator / ecuador

OCÉAN ATLANTIQUE
ATLANTIC OCEAN
OCÉANO ATLÁNTICO

OCÉAN PACIFIQUE
PACIFIC OCEAN
OCÉANO PACÍFICO

OCÉAN INDIEN
INDIAN OCEAN
OCÉANO ÍNDICO

Snake River Desert
Great Basin Desert
Salt Lake City Desert
Mojave Desert
Death Valley
Navajo Desert
Sonora
Imperial Valley
Chihuahua
Sechura
Atacama
Patagonia

S A H A R A
Grand Erg occidental
Grand Erg oriental
Tassili
Erg de Murzuq
Désert oriental
Désert lybique
El-Djouf
Tanezrouf
Ténéré
Borkon
Désert de Nubie
Kordofan
Sahel
Dankali
Ogaden
Namib
Kalahari

Kyzyl-Koum
Kara-Koum
Dzoungarie
Gobi
Ordos
Takla-Makan
Chang-Thang
Désert de Syrie
Negev
Sinaï
Grand Kévir
Lout
Sind
Grand Nefoud
Rub'al-Khâli

Great Sandy Desert
Tanami Desert
Gibson Desert
Great Victoria Desert
Simpson Desert

Les zones sèches dans le monde · The world's drylands · Las zonas secas en el mundo · الأراضي الجافة في العالم

Ce poster fait partie du ***Kit pédagogique pour les pays situés en zones sèches*** publié par l'UNESCO.
Le kit est disponible en quatre langues (anglais, arabe, espagnol, français) et il se compose de trois documents : ***le manuel de l'enseignant***, élément central du kit, ***le cahier de la classe*** à l'attention des élèves et le poster présentant ***la carte des zones sèches dans le monde***.

Responsable de la publication : Thomas Schaaf, UNESCO
Rédaction et conception du projet : Hélène Gille
Conception graphique du poster : Atelier Takavoir, Paris
Recherche iconographique : Amélie Dupuy, Cathy Lee
Impression : LM graphie

This poster is part of the ***Teaching resource kit for dryland countries*** published by UNESCO.
The kit is available in four languages (Arabic, English, French and Spanish) and comprises three documents: ***the teacher's manual***, the principal element of the kit, ***the class exercise book*** for pupils' uses and the poster presenting ***the map of the world's drylands***.

Officer-in-charge: Thomas Schaaf, UNESCO
Editor and project designer: Hélène Gille
Graphic design of the poster: Atelier Takavoir, Paris
Iconographic research: Amélie Dupuy, Cathy Lee
Printed by: LM Graphie

Este póster forma parte del ***Material educativo para los países situados en zonas secas*** publicado por la UNESCO.
El material está disponible en cuatro idiomas (árabe, español, francés, inglés) y se compone de tres documentos: ***el manual del profesor***, elemento central del material, ***el cuaderno de la clase*** dirigido a los alumnos y el póster presentando ***el mapa de las zonas secas en el mundo***.

Responsable de la publicación: Thomas Schaaf, UNESCO
Redacción y concepción del proyecto: Hélène Gille
Concepción gráfica del póster: Atelier Takavoir, Paris
Investigación iconográfica: Amélie Dupuy, Cathy Lee
Impresión: LM graphie

Source : CRU / UEA, UNEP / DEWA

Organisation des Nations Unies pour l'éducation, la science et la culture
Programme sur l'Homme et la biosphère
Ecoles associées de l'UNESCO