Water Resources Sustainability Project
(WRS)

Pilot Project for Control of Soil Erosion in the Oued Nakhla Watershed

Final Progress Report
January 1st, 1997 to December 31st, 2001

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Ministry of Environment

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Accomplishments of Nakhla Watershed Project: 1997-2001

Executive Summary

Soil erosion in the Rif mountains of northern Morocco is very important and affects dam siltation, aquifer recharge, and sustainable agricultural practices. The Rif mountains in northern Morocco are experiencing among the highest rates of soil erosion in the world. The Oued Nakhla watershed is representative of the soil degradation in the Rif and has been included as a priority watershed in the National Strategy of Watershed Management of the Government of Morocco. The Water Resources Sustainability (WRS) soil erosion control pilot project was initiated in 1997 with funding from USAID to reduce soil loss in the Oued Nakhla watershed and thus contribute to more sustainable water resources management.

The Oued Nakhla watershed has a number of physical characteristics that foster soil loss. The watershed lies in the northwestern part of the Rif Mountains in northern Morocco. It is situated between 35°19' of latitude north and 5°16' of longitude west. The watershed lies 20 km south of the city of Tetouan, on the road to Chefchaouen. It is approximately 10,630 ha in size with an estimated population of 8,000 inhabitants. There is a dam at the lower end of the watershed which impounds water destined for domestic use for the city of Tetouan. The reservoir was originally built in 1962 with a capacity of 9 million m^3. The Nakhla dam has lost 35% of its capacity since 1962 due to siltation.

The key features of the watershed's economy are crop and livestock production, which also contribute to soil erosion. Rainfed agriculture occupies a large portion of the cultivated area of the watershed. Crops cultivated on rainfed land include wheat, barley, maize, forage, and legumes. Irrigated agriculture only represents 10% of the total agricultural area and is practiced only in fields adjacent to water sources, where springs from the limestone ridge are found. Cultivated fruit trees include olive, fig, almond, pear, apricot, prune, carob, vine, and orange. Due to the small size of landholdings, the productivity of the land is very low. The average yield for major crops is generally well below the national average.

Livestock production plays an important role in the economy of the watershed and provides a major source of revenues for farmers. The animals kept in the watershed include primarily goats, sheep, and cows, with goats being the most prevalent. Heard sizes range from 3 to 6 for sheep, 4 to 30 for goats, and 1 to 5 for cows.

The low revenues generated from crop production prevent the introduction of more efficient techniques and exacerbate pressures on an already fragile environment. Livestock further deplete the watershed's resources by reducing the size of available land for cultivation and affecting the value of the matorral.

Three major factors trigger the process of accelerated erosion and result in important soil loss: (1) the expansion of cultivation over vulnerable lands; (2) livestock over-grazing causing the degradation of natural vegetation; and (3) the use of non-sustainable agricultural practices. The increasing needs of the growing population force people to move to new lands for farming. The degradation of the vegetation and of the soil are tightly linked the agricultural and pastoral practices.
WRS targeted four zones where project interventions will take place. A study of the rates of soil erosion in the Oued Nakhla watershed showed that 2,100 hectares (18 percent of the land area) contributesd more than 30 percent of the siltation in the reservoir at the Nakhla dam. Within this 2,100-hectare area, four zones were selected for the WRS soil erosion interventions. Zone 1 is the upland area in the southeast part of the watershed; Zone 2 is around the villages of Bouattou and Azzemour in the east-central part of the watershed; Zone 3 is around the village of Achekrade in the most heavily populated part of the watershed; and Zone 4 is centered around the village of Zerka on the western side of the watershed.

The pilot project included three direct interventions to reduce soil erosion originating from crop lands, existing gullies, ravines, and degraded matorral. The first group of interventions was aimed at reducing soil loss from sloping, dryland agricultural fields that mostly produce cereal crops. These interventions include the overplanting of cereals with olive trees, construction of cuvettes around trees, and planting of contour grass strips between trees. The second intervention is to control existing and actively growing gullies in the rainfed cropland zones through the use of locally constructed check dams and bank stabilization with shrubs and other vegetation. The third direct intervention was to reduce erosion in areas of degraded matorral by planting trees that are suitable for firewood production, and planting perennial grasses that can eventually be used as livestock forage.

The pilot project also included indirect interventions (beekeeping, improved cookstoves, irrigated fruit trees, environmental education, etc) designed to provide better management of the matorral, restore degraded areas, and prevent the further conversion of matorral for other purposes. The indirect interventions were designed to encourage and promote the preservation of the matorral (1) by increasing the economic gain that the people receive from the intact, functioning matorral, thereby increasing the value they place on it and thus their willingness to protect it; (2) by increasing the level of production and economic return from non-matorral areas, so that there will be less of a need to increase cultivated areas for subsistence; and (3) by increasing community awareness of the critical nature of the matorral and raising the level of knowledge concerning the ecology of the matorral so that its management can be improved.

The indirect interventions that were to be implemented by WRS include the introduction of mechanical equipment (metal plows, sprayers, threshing machines) to improve productivity on cultivated lands; the introduction of beehives, improved goat breeding, improved ovens, and the use of biogas to reduce the pressure on the matorral; and the development of community associations and erosion awareness programs to improve long-term management of the watershed's resources.

The major indicators of project success initially established for the WRS project were a 25% reduction in erosion on targeted steep cultivated dryland, a 92% reduction in erosion on the targeted degraded mattoral, and a 2.5% reduction in siltation to the Nakhla watershed reservoir. The actual accomplishments of the Water Resources Sustainability (WRS) project from 1997-2001 are summarized below (Table 1):

- Developed productive working relationships with Ministries of Environment and Agriculture, the Beni Karrich Work Center, the Agency for Development of the North, and the Tetouan Provincial Government.

- Planted 113,885 olive trees on 762 ha of cultivated dryland in zones 1, 2 and 3.

- Constructed cuvettes around all of the newly planted olive trees.

- Protected newly planted olive trees from animal grazing using 4 paid guards.

- Instructed farmers how to apply 0.5 kg ammonium sulfate fertilizer to all newly planted olive trees.

- Purchased modern agricultural management tools for spraying, pruning, sawing, cutting, and plowing olive trees. These tools are being loaned to project cooperators.

- Installed 156 ha of contour grass strips to control erosion between planted olive trees.

- Stabilized 3.5 km of ravines in zones 1 and 2 using 9,400 acacia plantings and 500 poplar tree plantings. Also installed gabions and check dams in 1.5 km of ravines in zone 1 to stabilize ravines.

- Distributed 50 genetically improved Spanish goats to cooperators in zones 1-4. The first 25 goats distributed have produced 105 offspring.

- Reseeded 11 ha of degraded private rangeland in zone 2 with grass forage.

- Formed one Women’s Cooperative and distributed one improved cookstove for 20 households, resulting in a 50% reduction in the amount of firewood they collect

- Introduced 100 beehives into zone 4, and formed one beekeeping association.

- Planted 12,800 fruit trees on irrigated terraces in zones 1-4.

- Developed a Geographic Information System database for estimating erosion in Oued Nakhla before and after project interventions. Erosion losses from the entire watershed have been reduced from 64 t/ha/yr before the project to 51 t/ha/yr after olive trees planted in the watershed reach maturity. This is a 21% reduction in erosion.

- Reduced erosion on dryland olive tree plantings by an estimated 190 tons/ha, or 144,780 t/yr for the entire planted area. Reduced sedimentation to the Nakhla Reservoir by 14%.

- Conducted numerous workshops covering all topics relating to project implementation activities. These topics included construction of cuvettes, beekeeping, goat production, grass strips, agricultural implements, improved crop production techniques for wheat and forages, disease and pest control in olives, cookstoves, and replication of project activities.

- Established numerous demonstration trials in four project zones concerning wheat and forage production techniques. These demonstrations address issues such as seeding rate, variety performance, fertilizer management, and tillage management.

- Conducted a workshop for project participants dealing with lessons learned.

- Started to replicate and extend the lessons learned in the Nakhla watershed to other zones in the Nakhla watershed, as well as in the Abdel Moumin watershed of the Souss-Massa in southern Morocco.

Most notable among the project successes are the annual reductions in erosion (90%)from steep cultivated drylands and siltation in the Nakhla Reservoir (14%). These accomplishments have provided significant momentum to the project, and significant interest by government agencies in replicating and extending the project. As envisioned at the start of the project, the goals for these two indicators were for a 25% reduction in erosion from steep cultivated drylands, and a 2.5% reduction in siltation in the reservoir.

Most notable among the failures of the project was the inability to restore any degraded public mattoral lands, institute rotational grazing management practices, or develop any significant alternative sources of animal fodder. These are largely because animal grazing activities in the mattoral concern public lands, and villagers were unable to come to consensus about improved management of these lands.

The remainder of this report provides additional detailed information concerning project activities, accomplishments, successes, and failures over the time period from 1997-2001.

Table 1: Indicators of Project Success		
Indicator	**Target**	**Actual Quantity**
✓ Sign Workplan Agreement with Project Partners	4	4
✓ Olive Tree Plantings	38,700	113,885
✓ Cuvette Construction	387 ha	762 ha
✓ Hire Guards for Trees	0	4
✓ Plant fruit trees for terraces	5,000	12,800
✓ Grass Strips Between Trees	183 ha	156 ha
✓ Develop Spring Water	0	5
✓ Number of farmers and families trained in conservation techniques	190	1240+
✓ Number of women's associations formed		
✓ Distribute cookstoves	4	1
✓ Stabilization of ravines	4	1
✓ Distribute Spanish Goats	3.1 km	3.5 km
✓ Reseeding Rangeland	25	50
✓ Beekeeping Operations	92 ha	11 ha
✓ Rehabilitate Mattoral	100	100
✓ Rotational Grazing	24,000 trees	none
✓ Reduction in Erosion (olives)	92 ha	0 ha
✓ Reduction in Erosion (olives)	12,700 t/yr	144,780 t/yr
✓ Reduction in Erosion (watershed)	25%	92%
✓ Reduction in Siltation	- - -	21%
	2.5%/yr	14%/yr

Feasibility Study

Selection of the Nakhla watershed pilot project site was the outcome of a feasibility study completed in October, 1997. The feasibility study was based on the results of baseline data collection using field reconnaisance in October, 1996, and on the results of a participatory landscape/lifescape appraisal (PLLA) conducted in November, 1996.

Background Data Collection

During initial visits to the Nakhla watershed in October, 1996, background data were collected concerning the causes of soil erosion, patterns in watershed hydrology and precipitation, spatial patterns in vegetative cover, and types of crops grown. It was discovered that the Nakhla reservoir, which supplies potable water for the city of Tetouan, had lost 35% of its storage capacity since its initial construction in 1962 due to siltation. It was estimated from water quality monitoring data that 18% of the watershed generated more than 30% of the siltation in the reservoir. The average rate of soil erosion from the entire watershed was estimated at 64 t/ha/yr, primarily from cultivated lands on steep slopes used for rainfed production of wheat, barley, forage, and legume crops. Other causes of soil erosion were due to degradation of the natural mattoral by over-grazing and exploitation for fuel wood, and erosion from gullies and ravines.

The zones most susceptible to erosion in the watershed were evaluated using background information from several sources. The first source, a satellite image, was used to delineate cultivated rainfed agricultural fields and degraded mattoral. The second source, a detailed soil map was developed to identify the vulnerability of various regions in the watershed to soil erosion. A third source, a topographic map of the watershed, was used to delineate slope steepness in the watershed. These three factors, land use, soil type, and slope steepness, were overlain. The resulting information was used to classify the watershed into broad categories of erosion risk, with the highest erosion risks from dryland cultivation on steep slopes and fragile soils. Several zones were delineated in this manner for implementation of erosion control activities in the watershed. These zones were small enough to be feasible for implementation of project activities, yet were large enough to be representative of the entire watershed.

Participatory Approach

The Participatory Landscape/Lifescape Appraisal (PLLA) was used to identify potential participants and stakeholders in the project, to develop rapport with new partners, to identify the basic characteristics of the production system and ecosystem, to identify the key constraints and potential solutions to soil erosion problems, and to develop a suite of proposed interventions to combat soil erosion. These proposed interventions were then developed into a final set of implementation actions during May, 1997 in a workshop attended by farmers living in the watershed.

Implementation Plan

Four zones within the 18% of the watershed that generates 30% of the siltation in the reservoir were chosen for implementation of project interventions to control erosion. Zone 1 consists of roughly 175 ha divided among rainfed cropland (150 ha), degraded mattoral (15 ha), and irrigated terraces (10 ha) near the villages of Bettara and El Ouadiyine. Zone 2 consists of roughly 96 ha divided into cropland (71 ha), degraded mattoral (15 ha), and irrigated terraces (10 ha) near the villages of Bouattou and Azemmour. Zone 3 consists of 180 ha divided into cropland (140 ha), degraded mattoral (30 ha), and irrigated terraces (10 ha) near Achekrade. Zone 4 consists of roughly 58 ha consisting of cropland (26 ha) and mattoral (32 ha) near Zerka.

A series of implementation actions with either a direct or an indirect effect on soil erosion were proposed for each zone. Direct actions included overplanting dryland cereals with olive trees, with bands of grass or forage between trees, and with cuvettes to collect water around the trees. Other direct actions involved physical and biological stabilization of gullies and ravines, or revegetation of degraded mattoral with trees and grass. Indirect actions included reducing the degradation of the mattoral by introducing energy efficient cookstoves, and by introducing genetically improved breeds of goats combined with rotational grazing techniques. Other indirect actions included introducing beehives into the mattoral, and introducing better cultural practices for dryland cereals and legumes. Finally, additional income generating activities were proposed such as rehabilitation of the irrigation canal network, fruit tree planting on the irrigated terraces, and raising small animals in domestic households. The successes and failures of the project in fully achieving these implementation plans are described further below.

Two major indicators of project success were established during the feasibility study. The first indicator was a target of reducing soil erosion in the watershed by 12,000 tons/yr. This involved a projected 25% reduction in erosion from the dryland cultivated fields after implementation of all planned interventions. It was initially anticipated that this indicator would be estimated using data from soil erosion plot measurements within the watershed. The second indicator was a 2.5% annual reduction in the loss of water storage capacity in the Nakhla reservoir.

Institutional and Organizational Arrangements

The project was implemented using a multi-institutional, multi-disciplinary partnership, with direct participation by farmers and villagers living in the watershed. The major partners included:

- The Provincial Department of Agriculture (DPA)
- The Work Center of Beni Karrich (CT)
- The Department of the Environment (DOE)
- The Wilaya of Tetouan
- The National Agency for the Development of Northern Provinces
- The Regional Department of Water and Forests (DREF)
- The Water Resources Sustainability Team (WRS)

Each of these signed a Workplan Contract at the beginning of each year. The Workplan Contract specified the roles and responsibilities of each partner, the specific implementation actions to be undertaken, the locations and timelines for these actions, and the quantity of each action to be implemented. The Workplan Contract also was very transparent in specifying the costs for each activity, and which partner would pay these costs. The Workplan contract was a very effective mechanism for ensuring the active participation of each partner, for ensuring good coordination of activities, and for reducing ambiguity and confusion in working relationships. Unfortunately, the Workplan Contract was not very effective at reducing administrative bureaucracy regarding procedures for tracking administrative working hours, obtaining signatures for various tasks, etc. In some cases, these bureaucratic problems hindered timely progress of the project.

It was initially anticipated that the partners would also include non-governmental organizations (NGOs) dealing with issues such as beekeeping, cookstoves, and management of the mattoral. Unfortunately, the project was never successful in involving NGOs, mainly because the NGOs were not focused on the geographic area encompassed by the project, and because of difficulty in financing NGOs through the project.

Each partner contributed to the project in different ways. Some of these include:

- Provision of local expertise and a local presence in education on production techniques (CT)
- Provision of manual labor, transportation, and equipment (CT, DPA, WRS)
- Ability to obtain villager signatures on contracts for collective use of water reservoirs and cookstoves (DPA, DOE, CT)
- Assistance with special needs relating to the importation and quarantine of genetically improved goats (DPA)
- Ability to provide cost sharing in project activities, particularly with the introduction of beehives, rehabilitation of the irrigation canals, and olive tree plantings (Agency for the North, DPA)
- Record keeping and report writing for project activities (CT, DOE, WRS)

Within the watershed, local participation was organized using villager committees. These committees were developed in the initial stages of the project, with one committee for each zone where implementation activities were targeted. These committees performed the following tasks:

- Develop a list of qualified farmers who wanted to participate in the intervention actions
- Organize farmer participation in implementation and education activities
- Help determine farmer preferences for various intervention options
- Obtain farmers signature on formal contracts for project benefits (trees, goats, etc)
- Help communicate and solve problems faced by farmers and project partners
- Coordinate project activities within each zone
- Assist in the implementation and management of interventions
- Help reduce misuse of project resources, and reduce conflicts between farmers

The village committees were critical to the success of the project interventions. Committee members were influential people in the village, and helped gain the confidence of participants. Villagers were initially suspicious of the involvement of government agencies, and were hesitant to participate. The village committees also were instrumental in providing the project with the ability to resolve unforseen problems, and to adapt to villager needs.

A final aspect of the project organization is the participation of local consultants to oversee the day to day implementation and management of interventions in the watershed. This was very critical to the success of the project. The frequent contact between local consultants and the villagers helped foster their confidence and participation. Frequent contact between local consultants and the members of the CT helped motivate and educate the people working in the CT. Consultants were also very important in writing regular progress reports for the project, and monitoring progress against goals.

Implementation Activities with a Direct Impact on Erosion

Olive Tree Plantings

The initial goal of the project was to plant 387 ha of steep cultivated dryland with olive trees along the contour at a density of 100 trees per ha for a total of 38,700 trees. By the end of the project, over a four year period, 113,885 olive trees had been planted on 762 ha in three project implementation zones. This figure includes replacement of olive trees which died due to water stress, illegal grazing, or diseases. The highest rates of mortality (25%) occurred after the first year of planting, because no supplemental irrigation water sources were available to combat drought, and no control measures were in place to prevent animal grazing on the young trees. During the successive years of the project, 7 reservoirs were constructed to store spring water, and guards were hired to prevent animal grazing in the olive tree plantations. As a result of these actions, the mortality rate for olive trees dropped to about 5% a year. An additional benefit of the restricted animal grazing was a significant increase in the level of soil cover after crop harvest by crop residues and weeds. This resulted in reductions in soil erosion that had initially not been anticipated.

Olive trees were provided to a total of 1240 village cooperators, although this number may include some duplicate cooperators whose land was planted in multiple seasons. The project far exceeded its initial goals for olive tree plantations, mainly because of overwhelming demand for the trees by villagers. Their interest was primarily motivated by the potential for large increases in their farm income from olive and olive oil production.

The surveying method for locating trees on the landscape was adapted to overcome several challenges. Surveyed locations were generally arranged so that the spacing between trees along the contour was 7 m, and the vertical drop between planted contour lines was 2 m. Due to the irregularity of the terrain and land ownership patterns, this was not possible in all cases. This planting pattern was designed to reduce the horizontal spacing between planted contour lines on steeper slopes (as small as 6 m), and increase the horizontal spacing on flatter slopes (as large as 14 m). This would allow the farmers on the steeper lands, which are very vulnerable to erosion, to eventually phase out cereal production by relying on the income from the olive trees. Locations of trees in adjacent contour lines were offset so that runoff water from the unplanted region on the upper slope would be intercepted by a tree on the lower slope. Difficulties in keeping to a regular system of tree spacing occurred on small irregularly shaped land parcels, especially near ownership boundaries. Trees were kept far enough away from boundaries to prevent disputes between landowners.

Cuvettes

Cuvettes were supposed to be constructed around each planted olive tree to catch runoff and sediment. These were supposed to be maintained throughout the year for maximum reductions in soil erosion. Villagers were reticent to construct cuvettes during the first year, primarily because of labor issues, and because of a lack of understanding about the benefits of cuvettes.

During the second year, an incentive was developed for the construction of cuvettes. Farmers were only given fertilizer for their trees if cuvettes were constructed around the olives. The CT held workshops on olive tree fertilization and construction of cuvettes. This strategy resulted in cuvettes being constructed on 70% of the olve trees planted in the second year, and 50% of the trees planted in the first year. During the third year, the DPA provided supplemental funds to hire laborers to complete the construction of cuvettes around all planted trees. Thus, by the end of the project, cuvettes had been constructed around all trees. Maintenance of cuvettes is still a problem. After farmers cultivate the land around olive trees in order to plant wheat or legumes, the cuvettes are destroyed. Only about 25% of the farmers in zone 1 have rebuilt their cuvettes.

Grass Contour Strips

According to the Feasibility Study, grass contour strips were supposed to have been planted on 183 ha of olive tree plantations. In contrast, only 6 ha of demonstration sites for grass contour strips were planted prior to the year 2000. From 2000-2001, another 150 ha of demonstration sites for grass contour strips were established in the olive tree plantations aroundAchekrade (zone 2).

This lack of initial success in planting grass contour strips was largely because farmers had no previous experience with them, and were reticent to adopt them. They were told that the strips would provide supplemental feed for their animals and would help trap eroding sediment. However, they felt that the inconvenience of interrupting tillage and planting operations with the strips outweighed the advantages.

Stabilization of Ravines

The Feasibility Study recommended stabilization of 3.1 km of eroding ravines in zones 1 and 3. The project actually stabilized 3.5 km in zones 1-2, using a combination of check dams, gabions, and plantings of acacia, oleander, and poplar trees. Ravines in zone 3 were determined not to require additional stabilization, since there are thick growths of oleanders in most ravines.

Some problems with stabilization of ravines were encountered. The first was that check dams and gabions were constructed without proper biological stabilization of slumping banks. As a result, bank slumping was considerable during the first year, leading to in-filling behind the check dams and gabions. The first oleander and acacia planting was haphazard, without treating slumping regions of the ravines. Most of the acacias planted died due to drought. During the second planting, biological treatment was much more successful. 4,800 acacias and 500 poplar trees were planted at regular intervals along 1.5 km of ravines in zone 1, and 4600 acacias were planted along 0.8 km of ravines in zone 2. These plantings are very healthy, and will have a significant impact on ravine erosion in the long-run.

Seeding of Rangeland

The Feasibility Study recommended reseeding 92 ha of degraded mattoral with grass seeds, forages, and carob trees. These lands are all in the public domain, and are used extensively for animal grazing and fuel wood collection. In actuality, only about 11 ha of private domain mattoral was seeded to grass, about 4 ha in 2000, and another 6.6 ha in 2001.

Project participants initially gave their approval to seed the public mattoral lands, and to plant carob trees. They also agreed to all tasks associated with grass seed planting, including labor, seeding, fertilization, and protection from grazing for a year and a half after planting. At last minute, the participants backed out of their agreements. Several reasons for this were given. These included a perceived difference in benefits from the revegetation to people with small versus large herd sizes. Also, there were isolated individuals within the community who, it was felt, would not honor the agreement to avoid grazing their animals in the newly seeded areas.

No successful examples for the implementation of rotational grazing on public rangeland were achieved during the project, despite the fact that the majority of the participants were well aware of the problems associated with degradation of the mattoral, and of the benefits of its restoration (reduced erosion, increased forage crops, increased fuel wood). This awareness was the result of numerous discussions and workshops about the mattoral with villagers. The only viable option for seeding grass on public lands is now hydroseeding, in which a pre-mixed slurry of seeds, fertilizer, and stabilizing mulch is sprayed onto the public rangeland using a tank truck.

Implementation Activities with an Indirect Impact on Erosion

Genetically Improved Breeds of Goats

The Feasibility Study recommended introduction of 36 male Murciano-Granadina goats, about one male for every 25 females in the targeted areas. The project successfully introduced 50 Spanish male goats during 2000-2001 into four zones in the watershed, due to overwhelming demands for goats. The first 25 males introduced into the herds have fathered a total of 105 offspring.

The introduction of goats was seriously delayed due to several factors. The first was an outbreak of disease among goats in Spain, leading to a ban on their importation for a year.

The second was a prolonged period of quarantine of imported goats to prevent transferrance of disease into Moroccan goat herds.

All 4000 head of goats in the target zones were immunized by the DPA prior to introduction of the improved goat breeds, to prevent the spread of disease from unimproved to improved goats. Nevertheless, 3 of the improved goats introduced into the watershed died. Several workshops were organized to teach beneficiaries of the improved goats proper techniques for control of parasites, for nutrition, and for reproductive methods. Some difficulties in ensuring proper management of improved goats were encountered due to a lack of participation by local experts in animal management.

Large herd owners tended to obtain greater benefits from the distribution of improved goats than small herd owners, since the WRS required a herd size of at least 25 for the distribution of improved goats. Small herd owners could receive improved goats only by pooling their herds with another small herd owner. This caused some difficulties and bad feelings.

Beekeeping

The Feasibility Study recommended introduction of 100 beehives in zone 4, along with all equipment necessary for extraction of honey. During 1999, 100 beehives were established by the Agency of the North in the dense mattoral of zone 4. They also purchased two sets of beekeeping equipment, including protective suites, knives, collectors, smokers, extractors, vats, and tubs. A beekeeping cooperative consisting of 25 villagers was formed to manage the beekeeping operations.

Due to severe drought and reduced availability of flowers and nectar in the mattoral, 25 hives were lost during the first year. In contrast, almost all of the natural beehives existing in the region prior to the WRS project perished in the drought. During the second year, continued drought, disease, and parasitism caused the loss of another 12 hives. Measures were taken to provide alternative sources of nourishment in the form of sugar and rose pollen. Not all of this was fed to the bees by cooperators. Proper oversight of the bee feeding operations by the DPA was inhibited by their lack of access to a vehicle due to mechanical problems with it. After learning of this problem, WRS paid to have the vehicle repaired. Additional measures are needed to ensure the sustainability of the beekeeping operations. Supplemental feeding operations are critical. Hives that are thriving could be split to replace hives that have died. The location of the hives should be moved to one that is more favorable in terms of availability of nectar and protection from parasites and predators.

Improved Cookstoves

According to the Feasibility Study, four improved cookstoves of the GEF-RIF type were to be introduced into the four target zones to reduce the consumption of firewood. In actuality, only one improved cookstove was introduced (during 2001) into the village of Bouattou (zone 2).

Endeavors to introduce improved cookstoves into the watershed were spearheaded by Maryam Bolata and a DPA Extension Agent from Tetouan (Aminah Hali). They conducted several surveys of women in Bettara and Ouadiyine (zone 1) to determine:

- The area from which wood was collected
- Time spent collecting wood
- Types of trees and shrubs cut for wood
- Quantity of wood collected
- Uses for wood collected
- Quantity of wood used to cook bread
- Villager preferences for various types of improved cookstoves

They found that the average weight of wood carried each day ranged from 25-60 kg. Women used from 12-20 kg of wood each day to cook bread, and as much as 40 kg of wood to heat 20 L of water for bathing (enough for a family of 9 people). They also found that women were very interested in reducing the time spent collecting wood (2-6 hours a day) through the use of improved cookstoves. However, women were very adamant in not wanting to share a stove with other households, and wanted their own individual cookstove.

It was decided to purchase one improved cookstove of the GEF-RIF type, a two compartment stove capable of cooking 12 pieces of bread in 15 minutes with 7.2 kg of wood. A communal shelter was built to protect the stove from rain and to vent the smoke. Women from 9 households in Bettara were trained in proper usage of the cookstove. The cookstove is being used by 20 households, at least four days a week, for four hours a day.

The quantity of wood being burned has been reduced from 12-20 kg a day to 6-10 kg a day (a reduction of 50%). As a result of the improved cookstoves, women have much more time for activities other than wood collection (education of their children, income generating activities). They are also less fatigued, both because of less time spent collecting wood, and because of less time spent cooking bread. They are also very satisfied with the quality of bread produced by the stoves.

Income Generating Activities for Women

A woman's association for poultry, rabbits, and crafts was established in zone 2 during 2001. This association is searching for sources of micro-credit, and for NGOs willing to assist in their training and development.

Management Improvements on Irrigated Terraces

Irrigated agriculture is a major source of income for villagers. Irrigated terraces are located primarily in the regions surrounding village habitations, and upslope of the rainfed cereal cropping system land. The cereal grain cropping systems supply a portion of the family income, and their reliance on this source of income could be reduced if the irrigated terraces were more profitable. If the villagers did not need to cultivate the rainfed cereal grain lands to obtain income, significant reductions in erosion would result. Therefore, rehabilitation of the irrigation canal delivery systems will indirectly reduce erosion rates in the Oued Nakhla watershed, but the amount of reduction is difficult to estimate.

The irrigation system for the village terraces is fed from springs which have relatively low flows (averaging perhaps 0.02 m^3/s), especially during the late summer when crop demands are highest (Ouattar, 1998). The efficiency of irrigation water delivery is poor, with losses in the delivery system prior to the irrigated terraces reaching as much as 80%. This high rate of loss is caused by several factors, including large infiltration losses in the channel of the primary delivery canal (it is unlined), poor design of secondary delivery outlets, and overall poorly maintenance.

In 1998, WRS consultant Mr. Ouattar studied the irrigation delivery network in zone 1 (near the villages of Bettara, Tzili, Ksoubatane, and El Ouadiyine) and found seven major rehabilitation needs, including:

- Lining the primary canals with reinforced concrete
- Improving secondary outlets and delivery systems
- Improving canals as they cross roads and ravines
- Improving canals where water cascades downslope
- Protecting springs
- Protecting steep slopes along the canal
- Developing auxilliary water sources

At the time, it was determined that the costs of the irrigation canal repairs (almost 2 million DH) were too high to be borne by the project, and that the money could more effectively be spent in planting olive trees which have a direct impact on erosion. Villagers were very disappointed by this decision. In February, 2001 it was decided by the WRS team to issue a call for a project to rehabilitate the irrigation network in zone 1. Financing for this project is anticipated from the Agency for the North.

To compensate for the disappointment expressed by villagers over the lack of improvements in their irrigation system, during the WRS team distributed 12,800 fruit trees to 459 recipients in zones 1-3. This included 3,838 plum trees, 3,457 pear trees, 2,942 apple trees, and 2,563 persimmon trees. Trees were planted on the perimeters of the irrigated terraces to stabilize the berms that control water flow. In the long-run, these trees will produce fruit that can be sold in market, leading to increases in household income.

Extension Activities

Education and Training

Farmers in the watershed received regular education and training prior to, during, and after the introduction of any new implementation activities. Such an approach reduced the risk of improper management, reducing the potential for failure of each intervention. As a result of the education and training, farmers gained confidence, knowledge, and new skills about each new management practice. Education and training sessions were organized and led by members of the CT and WRS consultants. Each session was repeated in each zone, and most involved the actual demonstration of each technique. Examples of the topics for education and training included:

- Olive tree planting and fertilization techniques
- Rationale and methods for constructing cuvettes
- Methods for controlling insects and diseases in olive trees
- Pruning techniques for trees
- Methods for planting, cultivating, and fertilizing wheat
- Methods for controlling weeds in wheat
- Crop rotation techniques
- Techniques for controlling diseases in legume crops
- Installation and maintenance of contour grass strips
- Importance of revegetation in the degraded mattoral areas
- Forage crop planting in the mattoral
- Techniques for measuring erosion
- Goat breeding techniques
- Goat nutrition and disease management
- Beekeeping management techniques (feeding, diseases, parasites, honey extraction)
- Disease control techniques in fruit trees
- Improved cookstove usage techniques
- Techniques for forming a women's association

Field Demonstrations

The CT installed numerous field demonstrations in each zone. Each of these were designed to show the effect of a variety of management practices on crop yield, with the emphasis on Best Management Practices (BMPs) in comparison to traditional practices. Farmers were taken to the sites of these demonstrations at harvest and were able to visually observe differences in crop yield across treatments. The type of treatments demonstrated for cereals, legumes, and forage crops included:

- Soil preparation techniques prior to seeding
- Fertilizer response trials
- Certified seed and variety trials
- Timing and method of weed and disease control (spray trials)
- Harvesting techniques
- Crop rotation trials

Field Trips

Field trips for farmers were organized to take them to see farmers in other regions who were already practicing the techniques that were going to be introduced in the Nakhla watershed. Examples include:

- Cheese factory in Chefchaouen
- Olive plantations in Loukous

- Goat farmers in Khenifra, Ouazzane, and Meknes

Seminars

Seminars were organized for members of the WRS team to review knowledge needed to implement some of the interventions in the watershed. Examples included:

- Erosion control workshop
- Goat management workshop
- Beekeeping workshop
- Lessons learned from the project

Public Relations and Publicity

The WRS project in the Nakhla watershed maintained good communication with government agencies, NGOs, and the public concerning the accomplishments of the project. Publicity about the project was accomplished using:

- Newspaper articles
- Television news interviews on Moroccan channel 2M ("Dounia" program)
- Public talks
- Field trips to view project progress for various ministers, ambassadors, and farmers
- Presentation of project results at various seminars and workshops

Reductions in Erosion and Siltation of the Nakhla Reservoir

PREM consultant Mohamed Khatouri developed Geographic Information System (GIS) thematic coverages and applications for the Oued Nakhla watershed. The objectives of his work were to provide visualization capacities of project activities, to estimate impacts of project activities on erosion and sediment transport to the Nakhla Reservoir, and to assist in dissemination of project results.

Thematic layers which are visualized using the GIS include:

- Nakhla Watershed boundary
- Nakhla Reservoir location, outline, and loss in capacity since 1961
- Clip art photo of Reservoir
- Digitized locations of streams and ravines in the Watershed
- Location of stabilized ravines
- Clip art photo of stabilized ravines
- Locations of soil erosion measurement plots
- Tables of soil loss values linked to erosion plots
- SPOT satellite images of the Watershed in 1995 at a scale of 1:25000
- Digitized elevation contour maps and slope steepness maps
- Locations of improved springs and reservoirs
- Locations of villages
- Locations of land parcels where rangeland improvements are demonstrated

- Locations where improved goat breeds have been introduced
- Clip art photo of improved goat breeds
- Location of Bettara Women's Association
- Clip art photo of women in the Association
- Boundaries of olive planting operations in zones 1-3
- Clip art photo of olive tree plantations
- Soil map of the Watershed, including 18 soil map units
- Linked table of soil properties measured for each soil map unit
- Land use map of the Watershed before and after the project activities
- Erosion rate map for the Watershed before and after the project activities

For the purposes of estimating impacts of the project activities on soil erosion and sediment transport to the Nakhla Reservoir, these GIS layers were used to estimate parameters of the Universal Soil Loss Equation (USLE):

$$A = R\ K\ LS\ C\ P$$

where:

A is estimated annual soil loss
R is the rainfall erosivity factor
K is the soil erodibility
LS is the slope length and steepness factor
C is the cover management factor
P is the conservation practice factor

The rainfall erosivity factor was estimated by PREM consultant Mhammed Tayaa using two years of precipitation intensity and energy data at two sites in or near the Watershed. An R value of 144 was estimated for the upper portion of the watershed, and a value of 93 for the lower portion.

The soil erodibility factor was estimated based on a soil texture index (M) and organic matter content (OM) using the equation:

$$100K = 2.1 \times 10^{-4} \times (12\text{-OM\%}) \times M^{1.14} + 3.25 \times (S-2) + 2.5 \times (P-3)$$

In this equation it was assumed that the soil structure code (S) had a value of 2. The soil permeability code (P) had a value ranging from 1 to 6, based on differences in permeability of soils measured by Rachid Bouabid. Permeability codes of 1 have greater permeability than soils with a permeability code of 6.

In general, erodibility values for silty soils are greater than values for sandy or clayey soils. Silt sized soil particles are moderately easy to detach and transport, whereas sandy particles are easy to detach but difficult to transport, and clayey particles are difficult to detach but easy to transport. Values of K ranged from 0.10 to 0.33, with the higher erodibility values for sandy soils, and the lower values for silts and clays.

Slope length and steepness (LS) factor values were estimated by Mr. Khatouri from the elevation contours and a flow accumulation algorithm developed for the Modified Universal Soil Loss Equation (MUSLE). The majority of the watershed has LS factors of approximately 10-20.

The cover management factor (C) was initially estimated by Dr. Tayaa for each land use practice studied in the erosion plots. Rates of soil erosion in the cultivated erosion plots are not representative of long-term rates in typical farmer fields because the erosion plots are not properly tilled, have dense weeds, and leak. In addition, drought conditions of the last three years are not representative of long-term climatic conditions, so the rainfall erosivity is too small. Therefore, the estimated C factors are from 2 to 3 orders of magnitude too small.

Improved estimates of the C factors for each land use practice were made by using data from erosion plots in Tunisia, and published values for similar crop rotations in USDA Handbook 537. The improved estimates for the C factor, along with estimates for the conservation management factor (P) are shown in Table 2 below:

Ravines are a significant source of sediment. Many of the gabions and check dams installed are completely filled with large stones and sediment. The source of this debris is slumping banks along the ravines. Surveys of the amount of sediment trapped behind gabions and check dams indicate that ravines produce sediment at a rate that is 25% of the rate in surrounding agricultural land. Thus, ravines produce less soil loss than agricultural land, but the amount is still significant.

Estimates of erosion rates in Oued Nakhla were obtained using the GIS data layers for USLE factors (R K LS C P) described above. The average rate of erosion estimated without project interventions using the GIS was 64 tons/ha/yr from vegetated land, and 16 t/ha/yr from ravines. After project interventions, erosion from vegetated lands will be reduced to 60 t/ha/yr with less than 5 years of olive tree growth, and erosion will be reduced to 51 t/ha/yr after 5 years of olive tree growth. Similarly, erosion from ravines will be reduced to 15 t/ha/yr after from 1 to 5 years, and to 13 t/ha/yr for from 5 to 25 years after implementation of project activities. This is a projected 21% reduction in erosion rates for the entire watershed due to project interventions after olive trees have reached maturity.

Table 2: Universal Soil Loss Equation (USLE) Cover Management (C) & Conservation Practice (P) Factor Values

Land Use	Erosion C Factor	Erosion P Factor
Wheat-Legume-Fallow	0.6	1.0
Wheat-Legume-Fallow w/Olives - Cuvettes		
Immature Olive Trees	0.45	1.0
Mature Olive Trees	0.05	1.0
Wheat-Legume-Fallow w/Olives-Cuvettes-Stripcrop		
Immature Olive Trees	0.34	0.8
Mature Olive Trees	0.01	0.8
Irrigated Terraces	0.9	0.5
Degraded Mattoral	0.18	0.5
Dense Mattoral	0.01	0.5
Forest	0.005	0.5

Reductions in erosion are even greater on the dryland cultivated lands planted to olive trees than for the entire watershed. As an example of the impact of project activities on soil erosion in cultivated drylands, consider the following scenario (Table 3). Olive trees with cuvettes have been installed on 762 ha of in zones 1, 2, 3, and beyond. This land has a rainfall erosivity of 144, a soil erodibility of 0.3, and an LS factor of 8. With conventional rainfed management before the project implementation activities (C factor 0.6, P factor 1.0) erosion rates on this land would have been about 207 ton/ha/yr. After olive tree plantings (C factor 0.45, P factor 1.0) erosion rates have been reduced 25% to 156 ton/ha/yr. In seven to ten years, when the olive trees mature (C factor 0.05), erosion rates will be reduced by 92% to 17 ton/ha/yr.

The impacts of this scenario on erosion and sediment transport in Oued Nahkla can be evaluated after multiplying erosion rates by the area of land planted to olive trees (762 ha). With conventional management, these 762 ha produce 157,734 tons of eroded sediment annually. With immature olive trees and cuvettes, eroded sediment decreases to 118,872 tons. When these trees reach maturity, eroded sediments will decrease to 12,954 tons. The total mass of sediment conserved with olive tree plantings is 38,862 tons for immature trees and 144,780 tons for mature trees. This reduction is far greater (more than 10 times greater) than the 12,700 t/yr of erosion projected to be reduced by the project during the Feasibility Study.

At a sediment delivery ratio of 0.15, a typical value for a 114 km^2 area watershed, these 762 ha of land deliver 23,660 tons of sediment annually to the Nakhla Reservoir under conventional management, 17,831 tons under immature olive trees, and 1,943 tons under mature trees. In the long-term (under mature trees), these 762 ha of land with mature olive trees will deliver to the Nakhla Reservoir 21,717 tons/yr of sediment less than the same land under conventional management. Since the Nakhla Reservoir is currently filling in at a rate of about 160,000 tons of sediment per year, the 762 ha of land planted with olive trees will reduce the rate of infilling by 14% per year after trees reach maturity. Thus, the project interventions will extend the useful lifetime of the reservoir by 14 years over the next 100 years. This reduction in the rate of reservoir sedimentation is far greater (almost five times greater) than the reduction of 2.5% estimated in the Feasibility Study.

Another way of evaluating the impacts of the project on siltation of the reservoir is to estimate the loss of reservoir volume before and after project interventions. Before the project interventions, the reservoir was losing storage capacity at a rate of 0.16 million cubic meters (MCM) per year. After olive trees which were planted on 762 ha in the Nakhla watershed reach maturity, the annual loss in storage capacity will be reduced to 0.138 MCM/yr. Again, this is a 14% reduction in the rate of loss in storage capacity in the reservoir.

Table 3: Impacts of Olive Tree Plantings (762 ha) on Erosion and Sedimentation

	Erosion Rate (t/ha/yr)	**Erosion Rate (t/yr)**	**Sedimentation in Reservoir (t/yr)**	**Loss of Reservoir Storage Capacity (MCM/yr)**
Before Project	207	157,734	23,660	0.160
With Immature Olive Trees	156	118,872	17,831	0.154
With Mature Olive Trees	17	12,954	1,943	0.138
Reduction	190	144,780	21,717	0.022
Reduction (%)	92	92	14	14

<u>Cost-Benefit Analysis of Project Interventions</u>

A preliminary cost-benefit analysis of the Nakhla watershed project interventions was conducted by Hassan Sebbar in 1997. The input data for this analysis included the unit cost of each direct and indirect intervention, the number of interventions, the duration of the intervations, and the area affected by the interventions. The analysis of benefits is based on factors such as unit price of commodities produced, the amount of each commodity produced (olives, wheat, goats, honey, etc.), and the costs of production. The benefits of olive and honey production are assumed to increase linearly over an initial period of ten years and then stabilize. The final step in the cost-benefit analysis was to estimate the Net Present Value (NPV) and the Internal Rate of Return (IRR). IRR values greater than 10% make the project financially attractive.

Results from the preliminary cost-benefit analysis showed that the major sources of NPV and IRR were obtained from indirect interventions such as rehabilitation of irrigation canals and planting of fruit trees on irrigated terraces, and from restoration of the mattoral. IRR values for olive tree plantings were projected at 8.9%, while IRR values for irrigated cropland and restored mattoral were 25.2% and 33.3%, respectively. Since the accomplishments of the Nakhla watershed project were primarily associated with olive tree plantings rather than with indirect interventions, it is likely that the financial benefits of the project to villagers will be significantly less than initially projected. This benefit could shift more in favor of villagers, however, as a result of project replication and expansion activities described below.

In order to complete the evaluation of financial impacts of the project, a second cost-benefit analysis should be conducted. This analysis should consider actual project interventions, as well as projected interventions during replication and expansion of the project in other parts of the Nakhla watershed. To facilitate this analysis, it will be important to institute mechanisms for tracking the improvements in crop and animal production attributed to project interventions.

Replication and Expansion of Project

Nakhla Watershed

The success of the Nakhla watershed erosion control project have been significant. The project has generated its own momentum. This momentum is due to continuing interest by villagers in the watershed to continue implementation actions, and due to the interest of USAID, governmental agencies, and NGOs in building on the project successes.

A complete plan for the Nakhla extension project has been prepared by consultant Fouad Rachidi. The interventions for the Nakhla extension project, termed the Water Protection and Management (WPM) project, include actions that have a direct as well as an indirect effect on soil erosion. The expansion of the Nakhla project within the Nakhla watershed is projected to occur over the next three years at a cost of 10 million DH. Half of this cost is expected to be provided by USAID, and the Agency for the North will match the budget at a level of 1:1.

The interventions for the WPM project are planned for implementation in the original 4 zones of the WRS project, as well as 4 new zones within the Nakhla watershed. The four new zones are near Zerka (zone 5), Amtil (zone 6), the hills to the west of the main road and across from existing zones 2 and 3 (zone 7), and near Beni-Mossa (zone 8).

Interventions that will have a direct effect on erosion in the new WPM project include 770 ha of olive tree plantings (120,000 trees), 160 ha of grass contour strips, 9.5 km of ravine stabilization, grass seeding of 230 ha of rangeland and mattoral. Actions that will have an indirect effect on erosion in the new project include plantings of 16,000 fruit trees on irrigated terraces, rehabilitation of 1.5 km of irrigation canals, construction of 25 reservoirs for spring water, introduction of 40 improved cookstoves, introduction of 450 beehives, initiation of 5 women cooperatives for chickens and rabbits, and introduction of 2 genetically improved milk cows. In addition to these interventions, there will be many educational and training activities. According to estimates made by Mr. Khatouri using GIS, these interventions will result in a reduction of watershed erosion rates to 7 t/ha/yr, a reduction of 90% from erosion rates prior to WRS project interventions.

Visual inspections of the Nakhla watershed in December, 2001 showed excellent progress in surveying the sites for new olive plantations in zone 7. Also observed was a new road being constructed in zone 6. This road poses a serious threat for sedimentation to a Nakhla River tributary located southeast of the road. The edges of the road should be protected from erosion through biological stabilization with acacia tree plantings.

Abdel Moumin Watershed in the Souss-Massa Region of Southern Morocco

The Souss-Massa River Basin produces a majority of the fruits and vegetables that are exported from Morocco. In addition to extensive irrigated agriculture, the basin supports extensive forests of rare trees such as Argan and Thuya. These forests are severely degraded as a result of mismanagement (over-grazing and wood collection) and drought. Tourism thrives in the Agadir region, leading to rapid urban growth and increasing consumption of already scarce water supplies.

Water supplies in the Souss-Massa River Basin are very scarce, due to low mean annual precipitation, reduced even further by several years of drought. The primary sources of water arise from surface runoff and springs in the mountainous areas along the boundary of the basin, and from relatively deep ground water aquifers. Numerous dams have been constructed in the basin to store surface runoff in reservoirs, these reservoirs are severely impacted by drought and by sedimentation caused by upland erosion on mismanaged rural lands.

USAID has requested that a component of the Watershed Protection and Management (WPM) project be established in the Souss-Massa River Basin to address the above issues. This component of the WPM project focuses on reducing soil erosion, reducing the spread of desertification through improved forest management, increasing water conservation and use efficiency, and improving water quality. The WPM project in the Souss-Massa focuses primarily on the upland regions (above the surface water reservoirs).

The WPM project builds upon the experience of the Water Resources Sustainability (WRS) project in the Nakhla watershed. The WPM project in the Souss-Massa River Basin will use methodologies developed in the WRS project. These include multi-disciplinary, multi-agency, participatory approaches, direct involvement of farmers and villagers, rapid implementation of actions that directly or indirectly reduce soil erosion and increase water conservation, implementation of activities that generate additional

income for participants (including women), and careful monitoring of indicators towards progress.

The WPM project will establish a pilot project to replicate the WRS project in the Bigoudine sub-watershed of the Abdel Moumin watershed located in the Souss-Massa River Basin of southwestern Morocco. The Bigoudine sub-watershed was selected after two survey teams visited and evaluated several candidate sites in the upland regions of the Souss-Massa River Basin.