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Traditional water management in Tunisia: contributions to environmentally sustainable agriculture

Jennifer Hill and Wendy Woodland

University of the West of England, Bristol, UK.
E-mail: Jennifer.Hill@uwe.ac.uk

Introduction

Environmental protection has been a foundation of Tunisia's long-term development strategy. Its roots can be traced to 1987 and the aspirations for social and economic reform that were held by Tunisia's first democratically elected government. More recent inspiration has come from the goals of the United Nations' Agenda 21, which arose from the Earth Summit of the United Nations Commission for Environment and Development in Rio de Janeiro in 1992. Responding to the Rio summit, Tunisia established a National Sustainable Development Commission in 1993 to ensure the integration of environmental protection into development. Operating in this way, it acted as a conduit for the drafting of a national Agenda 21 programme in 1995. This programme developed a strategy for the sustainable management and utilization of the country's water resources, including water management for agriculture (Ministry of Environment and Land Use Planning 2001).

Tunisia contains three different climate zones: Mediterranean, semi-arid and arid, which experience differing water availability. Due largely to these differences in potential water resources, there exist a number of distinctive methods of water management for agriculture. The northern Mediterranean region is dominated by modern reservoir-fed irrigation. In the semi-arid central part of the country modern dams have been constructed in the north of the zone, but rainwater harvesting and terraced wadi systems predominate towards the south. In the arid south, communities practice traditional rainwater harvesting within small hillside catchments. This paper compares two contrasting agricultural water management techniques to examine their environmental sustainability: traditional small-scale rainwater harvesting and modern large-scale dam irrigation.

Contrasting water management techniques and environmental sustainability

The locations of the case study areas within Tunisia are highlighted in Figure 1. The Matmata Plateau, in the south of the country, exemplifies small-scale rainwater harvesting and the Zeroud Basin in the central steppe highlights modern, large-scale dam irrigation.

Figure 1 The location of the case study areas in Tunisia

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The Matmata Plateau falls within the arid zone, with average annual rainfall varying between 100 mm to 250 mm. Actual evapotranspirative losses vary between 400 mm to 500 mm per annum resulting in a negative annual water budget of 200 mm to 300 mm (Frankenberg 1980). Valleys to the west of the Plateau are covered by loess deposits: aeolian sand and silt which easily form a surface crust, facilitating overland flow in catchments (Boers *et al.* 1986 a and b). The natural vegetation of alfa grass, with an average ground cover of 20 per cent, affords little protection to the soils during high intensity rains (Chahbani 1984). Central Tunisia can be divided into two geographical regions. To the west, the mountains of the Dorsale give way to the Plain of Kairouan in the east. The plain is covered in alluvial Miocene and Pliocene (clay-sand) deposits. Rainfall across the region varies between 200 mm to 350 mm per annum, but actual evapotranspirative losses reach 600 mm to 700 mm per annum resulting in a negative annual water balance of between 300 mm and 400 mm (Guillaud and Trabelsi 1991). The climate supports semi-arid steppe vegetation. With lack of plant cover and steep gradients in the highlands, runoff is collected rapidly by wadis that descend from the Dorsale.

Traditional rainwater harvesting

Macrocatchment rainwater harvesting (Pacey and Cullis 1986; Barrow 1999) has a long history in the Matmata Plateau, dating back many hundreds of years to the original Berber inhabitants. Here, climate, topography and soils together make rainwater harvesting very effective. The majority of rain falls as high intensity-low frequency downpours. Overland flow is generated rapidly and it travels quickly over the steep slopes, supplying water and soil to valley bottoms. Earthen check dams (tabias) are sited progressively downslope to trap eroded material from the valley sides and this material is levelled to form agricultural fields (jessour). Water that is trapped behind tabias after rain events infiltrates into the soil and it can create a temporary, phreatic water supply. The rainfall multiplier effect of rainwater harvesting depends primarily on the ratio of catchment area to cropped area. On the western outskirts of Matmata, a ratio of 6:1 translates into field sizes approximating 0.6 ha and catchment sizes of around 4 ha (Hill and Woodland 2003) (Figure 2).

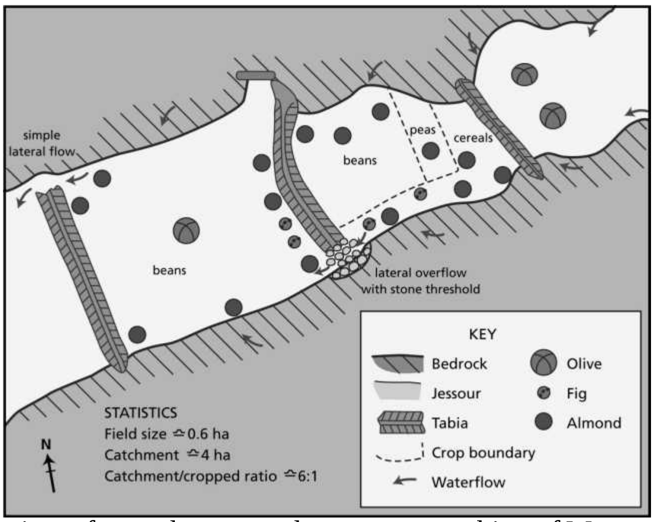

Figure 2 Plan view of a catchment on the western outskirts of Matmata. Average field sizes, tree spacings and catchment statistics, as measured by the authors, are highlighted

Vernacular knowledge and craftsmanship, derived from centuries of interaction with the local environment, has been used to construct tabias and equip them with overflows. These promote effective water distribution and allow some flexibility against climatic extremes. Lateral overflows are employed in 60 per cent of the tabias in the Matmata Hills (Bonvallot 1979). These are purpose-made breaches in the earthen bunds at valley sides which permit excess water to flow by gravity onto the terrace below, ensuring irrigation water with minimal erosive capability. Erosion of the overflows themselves is often reduced by strengthening their floors and sides with stones (Bonvallot 1986). The engineering of tabias, particularly the height of the overflow threshold, ensures that fields downslope are not deprived of water by higher fields, leading to crop failure. Equally, the height of the threshold prevents the build up of too much water after storms such that the root zone remains waterlogged for long periods. This enhances the agricultural potential by increasing root aeration and reducing soil salinization because water infiltrates efficiently and is used rapidly by crops (Rapp and Hasteen-Dahlin 1990).

Small-scale hydraulic works prove sustainable in the face of extreme events. An example is their response to exceptional rains in March 1979. Between the 3rd and the 6th of March, many parts of the Matmata Plateau received rainfall approaching their average annual total. The average annual rainfall of Matmata, for example, is 222mm, yet the area received 120mm in one day (Fersi 1978). These high intensity rains engendered catastrophic floods. The delegations of Tataouine and Beni Kheddache suffered the collapse of 70 per cent to 80 per cent of their agricultural bunds, whereas Matmata suffered damage of less than 10 per cent (Bonvallot 1979). Significantly, community work using local materials allowed a rapid response to the altered environment. These landscapes can be reworked effectively and they are thereby sustainable environmentally over long time frames and across climatic extremes.

Modern dam irrigation

The Kairouan Programme, initiated in 1975, centred on the construction of two large dams in the neighbouring Zeroud and Marguellil Basins. Financially and technically supported by foreign investment (via the Canadian Government), the aims were to reduce flooding in the Kairouan Plain, to develop irrigated areas downstream of the dams and to supply the city of Kairouan with an improved water supply (Guillaud and Trabelsi 1991). The Sidi Saad Dam, in the Zeroud Basin, came into service in 1982. By 1986, the dam was supplying water, via a system of gravity flow pipes, to irrigated perimeters up to 15km away (Guillaud and Trabelsi 1991). This led to a substantial rise in the acreage of olive and almond trees in the low steppe, and to an extension of market gardening using poly-tunnels for early winter fruit and vegetables.

Water flow in the Zeroud and Marguellil Basins had been regulated for centuries by means of a network of small barrages and 30 local dams. Such decentralised management maintained a number of spreading areas, which irrigated 30,000 ha and replenished local water tables (Figure 3a). The cost of these small-scale works has been estimated at only TD 6 million, as they utilised local equipment and 40,000 local labourers (El Amami 1986). This heritage could have been used to sustain decentralised water systems, but following the severe floods of 1969, which caused 150 deaths on the Kairouan Plain (Guillaud and Trabelsi 1991), the decision was made to construct a single large dam at Sidi Saad (Figure 3b). Costing TD 60 million, the dam initially supplied an irrigated area of 4,000 ha which has subsequently decreased to 1,000 ha (El Amami 1986). Although proving itself in terms of flood control during the heavy rains of 1990 (Guillaud and Trabelsi 1991), it has produced an irrigated area just one thirtieth of the size of the original, at ten times the cost.

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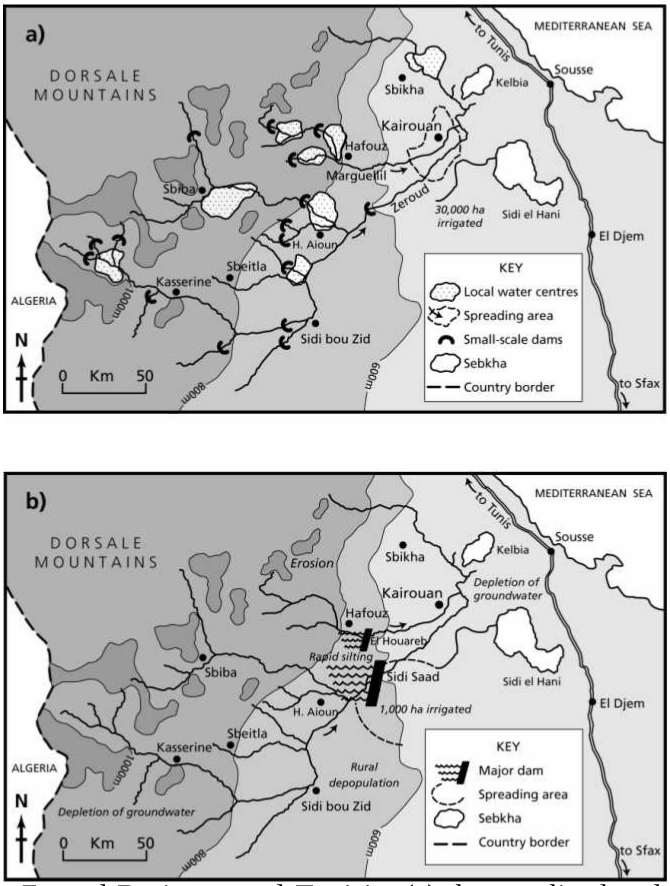

Figure 3 The Zeroud Basin, central Tunisia: (a) decentralized and (b) centralized water management (after El Amami 1986)

With an obvious economic disadvantage compared to small-scale hydraulic works, how do such large-scale developments compare in terms of long-term environmental sustainability? High intensity downpours falling on exposed friable soils in the centre of the country mean that the large-scale developments are liable to rapid, but spatially and temporally unpredictable, sediment input. Based on reservoir siltation rates measured between 1982 and 1993, the probable service duration of the Sidi Saad Dam has been calculated as 87 years (Zahar 2001). This figure falls notably short of the generational history recorded by the dryland jessour systems. Additionally, the Sidi Saad Dam would face a drastic reduction of its predicted service duration if it were to experience rains of similar magnitude to those of autumn 1969. These rains generated 2,500 million cubic metres of water at Sidi Saad measuring station in just two months, more than the annual average for all Tunisian watercourses. The discharge reached 17,050 cumecs on 27th September, an immense figure when compared with the annual average of just three cumecs. An estimated 275 million cubic metres of solids were mobilised, which is equivalent to 14 years sediment supply (Cruette *et al.* 1971). These figures must be compared with a flood spillway capable of evacuating 7000 cumecs and a storage capacity of 209 million cubic metres (Zahar 2001). If the dam had been constructed prior to the rains, it would have been unable to contain the flood peak and would have been filled completely with sediment. In Tunisia, large-scale water storage schemes provide some 66 per cent of the available water resources and demand for agriculture is increasing continuously (Baban *et al.* 1999). The storage loss to sedimentation is a problem that could well represent a serious threat to future agricultural development. The Sidi Saad reservoir will most likely have to be abandoned less than 100 years after construction (Zahar 2001); compare this with the continued use of depressions for rainwater harvesting in the south of the country which have been farmed for generations.

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The scale of the hydraulic works renders adaptive response to extreme events difficult. Dam walls are difficult and costly to raise to prolong life, unlike tabias when their jessour suffer rapid sedimentation. Dam structures must be sufficient to withstand high magnitude events from the outset, but predicting the vagaries of this marginal environment, where inter-annual variability of precipitation ranges between 30 per cent to 40 per cent (Frankenberg 1980), is notoriously difficult.

Reviewing sustainability

The efficiency of minor hydraulic works in southern Tunisia is currently being maintained, but a crucial development has reduced sustainability in the north: the abandonment of community based indigenous knowledge, which demonstrated physical adaptability to a dynamic and often extreme environment. Adaptability is the precursor to reliability and it is under threat in large-scale developments. Such developments possess rigid physical structures that are not easily adapted to the vagaries of climate. Modern large-scale developments have provided no more reliability over space and time than earlier small-scale works and they often result in less irrigated land per unit of water stored. Over long time frames modern developments are more susceptible to extreme events than community works. The only difference is that modern dam developments can provide short-term yield maximisation but this requires greater volumes of water, often leading to insidious environmental degradation.

The future: combining traditional and modern approaches for agricultural sustainability

The aim of the contrasting water management techniques described in this paper is to equilibriate spatio-temporal inequalities in water resources. Rainwater harvesting stores water in the root zone below the catchment during wet seasons to cover water requirements throughout growing seasons, whilst large dams store water above ground within the catchment to overcome annual and inter-annual deficiencies. There is a precarious equilibrium, however, dividing hydrological hazards and resources in Tunisia. Traditional management was able to physically partition the continuum between hazards and resources in favour of the latter through construction of jessour systems. Thus, a potentially hazardous environment of slope instability, flash flooding (*sensu* Graf 1988), soil erosion and drought was transformed into a secure environment by resourceful management. It was achieved by subtle manipulation of the landscape at micro and local scales using trial and error practical experience and drawing upon a community memory that allowed prediction of future success or failure. Collective community action and cumulative knowledge allowed high reliability farming. The environment was not perceived as risk-laden and therefore ‘critical’ but as reliable (Kasperson *et al.* 1996). The communities demonstrate a history of sustained production in difficult environments and it is likely that such adaptability and flexibility will continue to sustain agriculture into the future, if it can survive the threats of modernisation via new settlements and the lure of employment in the service sector of major cities.

Across Tunisia, new waves of proactive water conservation measures are being implemented (Ministry of Agriculture, 1998; Ministry of Development and International Cooperation 2002). Tunisia’s submission to the Rio +10 conference, for example, cites the implementation of “works aimed at water and soil conservation (treatment of slopes with water-retention systems, structures for spreading and mobilizing flood waters, “jessours”, etc.)” (Ministry of Agriculture and Land Use, 2001, p.56). One such example is a soil and water conservation programme, centred in the Governorats of Kairouan, Siliana and Zaghouan, which began in 2000. The project exemplifies the balance that can be achieved between large-scale centralised development and small-scale decentralised management

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based on modernised indigenous technology and undertaken with local participation. The programme is managed jointly by the Directorate for Water and Soil Conservation of the Tunisian Ministry of Agriculture, the United Nations' Food and Agriculture Organisation and the Italian Government. The programme has encouraged an increased uptake of field-scale water harvesting methods and it has helped local farmers to create a network of small hillside dams to collect surface runoff, a technique which began to be introduced at a national scale during the 1990s. The programme makes local people proactive and autonomous in the pursuit of local sustainable development and it engenders in them a sense of ownership within natural resource management. By 2001, as part of this programme, 586 small reservoirs and 224 small hilltop dams had been completed throughout Tunisia (Ministry of Agriculture and Land Use Planning, 2001). These second generation works have reduced siltation rates in the large dams and, through basal seepage into sand, replenished local aquifers (Grünberger *et al*. 1999; Montoroi *et al*. 2001). This encourages rural populations to remain settled as the groundwater reserves help reduce the risks of crop cultivation in an unpredictable environment.

The process of water development in the centre of the country appears to be coming full circle with a return to small-scale management to complement and sustain the large-scale hydraulic works. Such a dovetailing of different scales and technologies, integrated under a national planning structure, promotes a controlled but flexible approach to water management. This is crucial to long-term viability as it does not simply absorb indigenous expertise, but allows local voices to be heard in terms of hydrological and financial requirements (Richards 1985; Agnew and Anderson 1992). Indeed, a mix of modern and traditional methods, integrating international negotiation across territories and local participatory community management, seems to have been acknowledged as the practical foundation to sustainable water supply in the new millennium.

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