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Traditional agricultural water management in Tunisia: contributions to environmental sustainability

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Résumé
Des aménagements traditionnels en zone semi-aride de Tunisie ont transformé des paysages sujets à des inondations, des pentes instables et des sols érodibles en des environnements pleins de ressources. Ces transformations ont été atteintes grâce à des interventions bien adaptées à l'échelle locale. Les grands barrages modernes, par contre, sont des structures rigides bien plus sensibles aux précipitations extrêmes et à l'envasement rapide. Les auteurs suggèrent que la combinaison des deux pourrait apporter une bonne base pour optimiser la gestion des eaux.

Introduction

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 largely 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 Matmata Plateau, in the south of the Tunisia, exemplifies small-scale rainwater harvesting and the Zeroud Basin in the central steppe highlights modern, large-scale dam irrigation. The Matmata Plateau falls within the arid zone, and experiences a negative annual water budget of 200 to 300 mm. Valleys to the west of the Plateau are covered by loess deposits which easily form a surface crust, facilitating overland flow in catchments. The natural vegetation of alfa grass affords little protection to the soils during high intensity rains. 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 deposits and the region experiences a negative annual water balance of between 300 and 400 mm. With a 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 has a long history in the Matmata Plateau, where climate, topography and soils together make the technique 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 where it creates a temporary, phreatic water supply. 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).

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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 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. 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.

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. These high intensity rains engendered catastrophic floods. The delegations of Tataouine and Beni Kheddache suffered the collapse of 70 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. The aims were to reduce flooding in the Kairouan Plain, to develop irrigated areas downstream of the dams and to supply 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 1a). 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 1b). 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.

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 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. 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. 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. Storage loss to sedimentation will most likely mean that the Sidi Saad reservoir will 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.

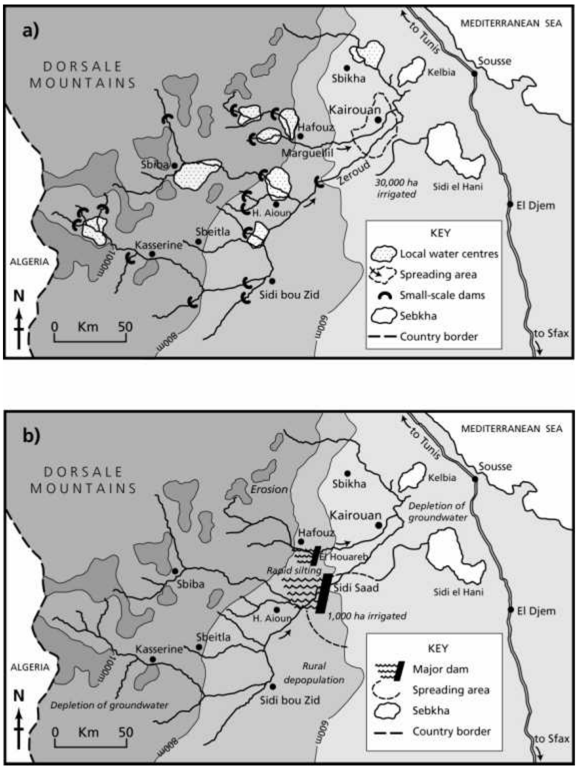

Figure 1 The Zeroud Basin, central Tunisia: (a) decentralized and (b) centralized water management (after El Amami 1986)

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. Such developments possess rigid physical structures that are not easily adapted to the vagaries of climate. 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 is high is notoriously difficult. 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 shortterm 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 equilibrate spatio-temporal inequalities in water resources. 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 flash flooding, slope instability and soil erosion 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 that drew upon community memory. Collective community action and cumulative knowledge allowed high reliability farming. The environment was not perceived as risk-laden and therefore 'critical' but as reliable. 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. 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.). 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 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 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. These second generation works have reduced siltation rates in the large dams and, through basal seepage into sand, replenished local aquifers. 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. 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 use in the new millennium.

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