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BANI IRRIGATION: AN ALTERNATIVE WATER USE

Marc Andreini[a]

INTRODUCTION

In Zimbabwe *bani* irrigation is a largely unacknowledged small-holder irrigation type. *Banis* may be described as any flat, grass-covered depression at the head of streams within the tropics which lacks a definite channel (except perhaps in their lower parts), and which is essentially saturated (Boast, 1990).

The *bani* irrigation systems typically constructed by communal farmers are composed of small fenced plots. The gardens are usually placed adjacent to one another, often sharing common fences (except in areas where the *banis* are, as yet, lightly exploited). Pumps are very infrequently used. Water is piped from springs, diverted in small channels from streams, or lifted with buckets from shallow hand-dug wells. Gardeners grow maize, rice, and a variety of horticultural crops, to market or for home consumption.

Banis represent 1.28 million hectares or 3.6 percent of Zimbabwe (Whitlow, 1984) and there are 263,000 ha of *banis* in communal areas (Bell and Hotchkiss 1989). It is estimated that 15-20,000 ha of banis are currently under cultivation in communal areas (Bell, Falkner, Hotchkiss, Lambert, Roberts and Windram 1987). The irrigators grow maize and horticultural crops. Generally, *bani* plots range in size from less than 0.1 to 0.5 ha. From the national perspective, *bani* irrigation is considered a land use of dubious value. Government policy with respect to those wetlands has been more concerned with the conservation of water resources.

Bani cultivation is regulated by the Streambank Protection Regulation of 1975 and the Water Act of 1976. The Streambank Protection Regulation does not allow cultivation within 30 meters of a streambank or on a wetland (Government of Rhodesia 1975 in Bell *et al*, 1987). Although the Water Act could be interpreted to require that permission be obtained to use water for other than primary use (drinking, cooking, washing, and stock watering), hand watered garden irrigation is often interpreted as a primary use and therefore not requiring permission (Bell *et al*, 1987).

Wetland is officially defined as: "Land that is saturated to within 15 centimeters of the surface for the major part of a rainfall season of average or above average rainfall and which may exhibit one or more of the following characteristics:

- the presence of mottles or rustlike stains in root channels within 15cm of the surface;

- a black topsoil horizon very rich in organic matter overlying pale leached sands; and

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- a dark grey or black heavy clay showing considerable surface cracking when dry."

(Government of Rhodesia 1975b in Bell *et al* 1987).

These legislative restriction were not based on a thorough understanding of *bani* hydrology, nor was the sustainability of the farming techniques considered when they were drafted. The *banis* being cultivated produce yields per unit land and yields per unit water which are higher than those obtained on formal smallholder irrigation schemes (See Chapter 5). It appears that existing legislation unnecessarily restricts their development. This study examines the relationship between *bani* hydrology and the water management practices of the irrigators. Its purpose is to further understanding of the ecology of this system and to provide information to the planners and legislators who will ultimately revise these laws.

METHODOLOGY

Since the methodology employed to study *bani* hydrology and management practices was different from that used in other sites, it requires further clarification in this chapter. The methodology employed a combination of techniques from the engineering and social science disciplines. Four formal surveys were conducted, the sites were mapped, and physical measurements made. Informal discussions with farmers, Agritex employees, and local community leaders also enriched understanding the issues involved.

Four representatives *bani* irrigation schemes were chosen for this study. They are located at Dufuya, Maboleni, Mbiru and Mushimbo. Table 6.1 summarises the physical characteristics of these schemes and their watersheds.

Hydrologic data were collected daily at each of the sites. Small meteorological stations were installed at a homestead adjacent to each site. Groundwater elevations were measured by monitoring the depth of the water in a small array of wells (four to six) at each site.

Local enumerators were responsible for monitoring the farmers' irrigation practices. The sample irrigators filled out a form which was collected every two weeks, reporting the number of hours they spent irrigating, the type of persons doing the irrigating, the method of irrigation, and the types of plants irrigated. Scheme level information was collected by means of questionnaires filled out by the Agritex dryland extension agents in whose wards these systems were located, and the irrigation infrastructure of all the sample gardens was inventoried.

WATER BALANCE

Banis are typically at or near the headwaters of drainage areas. While the movements of the water through any *bani* may be a subtle process that is not easily understood in detail (McFarland, 1990; Bullock, 1992b; Boast, 1990), their location at the top of the fluvial network simplifies the analysis. Estimates of the water available in *banis* are not complicated by stream flows originating in extensive, complex systems upstream of them. Figure 6.1 shows a schematic representation of the *bani's* hydrological system. It may be conceptualised as having three components: the watershed, the groundwater reservoir, and the *bani* itself. Rain falling on the *bani's* watershed either returns to the atmosphere as evapotranspiration, percolates into the ground as recharge, or flows across the surface to the *bani*.

The water balance is

$$G + R = ET_n + ET_c + SF + \Delta gs \qquad (1)$$

where:

Gr	=	Groundwater recharge from the watershed
R	=	Rainfall on the *bani*
ET_n	=	Evapotranspiration from the *bani's* natural vegetation
ET_c	=	Evapotranspiration from the crops
SF	=	Streamflow from the *bani*
ΔG_s	=	The change in groundwater storage.

The importance of infiltration from the uplands was long ago recognised by Rattray, Cormeck and Staples (1953), who stated that cultivation of the upland has a greater impact on the moisture of a *bani* than cultivation of the *bani* itself. The contribution of the watershed to the *bani* from surface runoff is negligible in these systems and, therefore, is not included in the water balance.

Water enters the *bani* from the watershed as recharge migrating below the surface or as rain falling directly onto the *bani* itself. It leaves the *bani* as evapotranspiration from crops and natural vegetation, or as stream flow. The relative rates at which these processes proceed determines the availability of water for irrigation.

Pan evaporation and rainfall were measured at each site. The groundwater monitoring well records demonstrate that the water levels remain reasonably stable throughout the year. There is not an annual deficit. Most of the minor fluctuations in the groundwater levels are attributable to storm events during the rainy season. During the dry season, the levels remain fairly steady. Therefore, we assume that there will be no long-term change in the groundwater storage, $\Delta Gs = 0$ and we can drop the change in groundwater from the equation. Groundwater recharge from the watershed is estimated with the Thornwaite-Mather procedure, using the daily values of rainfall and potential evapotranspiration from each site. Actual evapotranspiration is a function of the moisture remaining in the soil and the algorithm estimates percolation to the groundwater by calculating the water balance within the root zone (Thornwaite and Mather, 1955, 1957).

Water is a factor substitute. It can be used as a substitute for resources in more limited supply. The realisation that the concept of water use efficiency tends to obscure the relationship between water and the other inputs (Levine, 1977) led to the eventual development of the concept of relative water supply (RWS) (Levine, 1982) declined as supply divided by the demand. This inverts the more familiar notion of engineering efficiency (demand/supply) and focuses attention upon the independent role of supply in the analysis of irrigation system management.

The terms of the water balance can be rearranged to develop an expression for the relative water supply. The usual definition of demand must be modified for an analysis of *bani* irrigators. In *bani* systems, the crops are often consuming water supplied by irrigators, while taking a significant portion of their water directly from the capillary fringe. Although there are occasionally areas in the system where there are downward fluxes due to over-irrigation, water "wasted" as percolation is simply returned to the groundwater reservoir remaining available for use by other gardeners. Therefore, seepage is not considered part of demand. In these irrigation systems the expression for demand, D, is shortened to

$$D = Et_c \qquad (2)$$

The irrigations systems supply, Su, is described by the expression,

$$Su = Gr + R - Et_n \quad (3)$$

The stream flow exiting the *bani* is not included in the expression for supply because it is accounted for as recharge of rainfall entering the *bani*. The only outflow that should be subtracted from the supply is storm flow. Storm flows may be unavailable to the irrigators because they exit the *bani* very quickly. There were approximately nine large storms during the study year. The measured discharge from these storms was approximately four percent of supply on Dufuya. It can be assumed that the measured storm flow does not accurately capture the peak flows (the weir was overtopped five times). Using the crude assumption that all the storm rainfall on the *bani* exited immediately, a generous estimate of approximately 20 percent of supply was calculated by multiplying the storm rainfall by the area of the *bani*. This estimate falsely assumes that none of the water falling on the *bani* infiltrates or is captured as surface storage. Therefore, it can be speculated that the true storm flow losses are somewhere in-between these figures, on the order of 10 to 15 percent of supply. The storm flow is not subtracted from the supply because there are no measurements of the storm flows at any of the sites. Given the accuracy of the other components of this model, this results in slight, but tolerable inflation of the supply estimates.

Substituting the new expression for supply and demand, relative water supply, RWS, is:

RWS = Su/D (Equation 4)

or

RWS = (Gr + R - ETn)/ETc (Equation 5)

Table 6.2 shows the estimated values of the terms of Equation and the estimated relative water supplies of the four *bani* systems.

As Bullock (1992b) states, "a single model of *bani* hydrology has not yet been developed". Nonetheless, these estimates are consistent with and understanding of *bani* hydrology that may be pieced together from recent studies. Allen (1987 in Boast, 1990) has demonstrated, by the use of piezometers, that head increases with depth beneath *banis*, indicating upward flow, and head decreases with depth in the surrounding interfluves, indicating downward flow. He concluded that this evidence suggests that recharge flows from the upland into the *banis* with net discharge leaving the *banis*. Using evidence from an extensive database of up to 110 gaged catchments, Bullock (1992a) concludes that *banis* are an indiscriminatory factor in determining annual runoff from catchments at the regional scale and that there is no evidence that they significantly contribute to the maintenance of base-flow or dry season flow regimes. In other words, *banis* do not appear to be sponges absorbing water during the summer and slowly releasing it during the winter as asserted by Balek and Perry (1973). The channels below Maboleni and Mushimbo are dry except during storm events. At Dufuya, the stream flows are negligible most of the year. If water coming from the uplands is entering the *banis*, but the *banis* are not making significant contributions to dry season flows then much of the water must be lost to evapotranspiration (Boast, 1990) and this is what the figures in Table 6.2 suggests. These data provide a description that is consistent with the current state of knowledge and suggest that these systems are sustainable at current levels of exploitation.

Allocation of land is done by existing local institutions in such a manner that the systems do not grow uncontrollably. Dufuya's RWS is estimated to be 2.7 and Mbiru is 3.4. Both values indicate that there is more water available than is needed by the existing gardens. The RWS for Maboleni and Mushimbo are estimated to be 1.7 and 1.5 respectively. These values imply that supply is approaching demand and further expansion of these systems would result in potential water scarcities.

The sample irrigation systems have evolved without government participation or supervision, and decisions to use *bani* land have been made at the local level. The farmers' perceptions of what resources are available and what options they have are important if a consensus is to be reached within the community and the decisions of traditional leaders are to be supported.

Farmers' perceptions of the availability of resources are generally accurate, and they are willing to limit the expansion of their systems when land and water resources become fully allocated. Forty-one percent of the farmers at Dufuya feel that more gardens should be added, 25 percent at Mbiru, 18 percent at Maboleni, and 17 percent at Mushimbo. Higher percentages of farmers advocate system expansion at Dufuya and Mbiru where land and water are not fully allocated, than in Maboleni and Mushimbo were there are fewer resources remaining available.

Estimates of the size of these systems were made from aerial photographs taken periodically from 1965 to 1985. Figure 6.2 is a plot of the growth of these *bani* systems.

Bani land allocation is proceeding smoothly, despite the competition for grazing. The gardens are allocated by the traditional leaders and there is a consensus as to the availability of resources that reflects the actual conditions on the *bani*. When the resources are fully subscribed, the systems tend to stop growing.

In 1991, Maboleni and Mushimbo, the systems more fully exploiting their *bani's* resources have stopped growing. Dufuya and Mbiru, the systems with available water and space, continue to grow.

These findings indicate that *bani* systems are not being expanded until the resources of their watersheds are stretched far enough to require an uncomfortable level of system management. They do not grow until all of the potentially irrigable land, that is, the hydraulic command area in the *bani*, is filled.

IRRIGATION PRACTICES

This analysis suggests that these patterns of water use are sustainable, and that *bani* irrigation is a flexible, efficient year-round production system. Table 6.3 shows the cropping patterns observed during the 1990/91 seasons. The *banis* are cropped most of the year as the total. Percentages indicate, but there are seasonal variations in the crops planted.

In the summer green maize and other horticultural crops are grown. The gardens are more fully exploited in the summer season, but maize accounts for almost two-thirds of the cropped area in the summer. In the summer, less irrigation effort takes place because it is raining and the maize is cultivated as a dryland crop. In the winter, maize is absent and a larger quantity and variety of vegetables are grown than in the summer. More irrigation effort takes place in the winter. Theisen (1975) observed somewhat similar cropping patterns in the Kwekwe Communal Area. There *banis* were planted with green maize early in September and then intercropped with rice when the first rains came and during winter vegetables were planted. The consistency of this pattern across the *bani* sites and the supporting observations from Kwekwe suggest that this pattern is somewhat typical of *bani* production.

Dividing the year into wet and dry seasons is very useful for the analysis of water use because the contrast between summer and winter conditions is so vivid and the response of the farmers so different. But farmers do not plant only two crops a year. Farmers are not constrained to plant at rigidly specified times because of the mild weather conditions year round. They plant and harvest to optimise the usefulness of their output. Sometimes the gardens are full and at other times they are almost empty.

Table 6.4 displays sample farmers' responses to questions about their planting strategies. Three-quarters of the farmers report that they time their planting to get higher prices in the markets. Also it was observed that most of the farmers stagger the planting of the more popular crops. Tomatoes, onions, and garlic were often in a series of plots, each planted a few weeks after its predecessor.

Approximately 70 percent of the farmers claim to stagger the planting dates of important crops. Of these, 86 percent reported that they intended to produce food for home consumption over a prolonged period. About half of the farmers also reported that they stagger the planting dates to ensure some of the produce can be sold at peak prices. None of the farmers report that water shortages, the reliability of their supply, or their ability to control excess water, played a role in their decision to stagger their production. In contrast, dryland production is often staggered to deal with the unpredictability of the rainfall. Farmers plant some of their dryland crops with the first rains, more four to six weeks later, and the remainder at mid-season. This tactic is intended to ensure the success of part of the crop, regardless of the timing of the year's drought (Nyamapfene, 1989).

Figure 6.3 shows the water applied by the farmers in each system. At Mbiru, the site whose groundwater remained significantly lower than at the other sites and which experienced less rainfall during the study period, farmers were applying markedly higher quantities of water than elsewhere during the summer. At Dufuya, Maboleni, and Mushimbo, the majority of the irrigation was done during the winter. The *banis* were drier in the winter and farmers were not occupied with the work of tending their dryland crops.

There are no schedules or problems of reliability imposed on the farmers by the demands of an organised water distribution system. Farmers are free to use water as they please, without permission, consultation, or consensus. In the summer almost all of the farmers are irrigating to establish their crops (see Table 6.5). After the plants are mature enough, they thrive on precipitation and water extracted from the capillary fringe. The majority of the farmers irrigate only intermittently to supplement during dry spells. At Dufuya and Maboleni farmers reported lower percentages of supplemental irrigation because there are areas in these schemes that require no extra water at all. During the winter, all but approximately 20 percent of the farmers irrigate more regularly to compensate for the lack of rain.

Table 6.6 shows irrigation water as a percentage of the total garden demand for the summer and winter seasons. The depth to the water table beneath the gardens is not uniform. Some gardens are waterlogged, some enjoy near ideal conditions, and for some, ground water is unavailable to the plants' roots. Therefore, some farmers rely almost completely on groundwater and others supply large percentages of the plant requirements by irrigating. These figures may underestimate the contribution of the irrigation water because the evapotranspiration estimates are based on the assumption that the plant water uptake is unrestricted, while in actual fact the plants often appear water stressed. These caveats aside, Table 6.6 demonstrates that although irrigation is critical to the production of these crops, it represents a small percentage of the water consumed. While the exact magnitudes of these figures may be questioned, it is clear that the trends they illustrate are significant. The bulk of the demand is taken by the plants directly from the groundwater. Although the delivery technology is labour intensive, the portion of water required actually lifted and carried is typically quite small.

IRRIGATION TECHNOLOGY

Garden irrigation is a very labour intensive activity involving little mechanisation. Buckets, hoses, and had-dug channels are used to convey the water to the plants. There are four innovations that are being adopted to improve the use of water within the gardens.

Farmers:

- install gravity feed systems ;
- install hand pumps;
- grow rice in the wetter areas; or
- plant on raised beds.

Gravity fed systems are an innovation already being constructed by some farmers (see Table 6.7). Water is delivered to the plants through channels, hoses, or some combination of the two. Of the four schemes studied, all but Mbiru have some form of gravity fed systems already in place. Approximately 95 percent of the plots at these three sites could be serviced in this manner.

Bani irrigators acquire their irrigation water from three related sources: wells, fish ponds, and sponges. The majority of the water plants consume is acquired directly from the capillary fringe. Table 6.7 is an inventory of the water use infrastructure built by the farmers. Eighty-four percent of the garden plots have wells. Most gardens have only one or two wells, but larger gardens have more wells both to increase their storage capacity and to minimise the distance bucket irrigators must carry the water.

Table 6.8 also shows the average depths of wells in each system. Dufuya has the highest water table and, as expected, the wells are very shallow, averaging, 0.6m in depth. Maboleni and Mushimbo also have high water tables. At Maboleni wells average 0.8m in depth and at Mushimbo they average 1.0m. Mbiru has the deepest water table and, consequently, it has the deepest wells, still only averaging 1.8m. Shallow wells are essential to the smooth operation of these systems because the water table cannot be lowered appreciably with a shallow well. It is very important to note that nowhere do the wells penetrate the aquifer to a depth of more than one meter.

Table 6.7 shows the irrigation methods used by farmers. Irrigators using channels control the water by using a hoe to dig temporary ditches, building small dikes, and building or removing ad hoc checks. Channel systems require less effort than do buckets, but more than hoses. Hose irrigators simply move their hoses about their gardens. All gravity feed systems eliminate the work of lifting the water to the surface.

Hose irrigation has distinct advantages over buckets and open channels. Hose irrigation is not very strenuous. Because the hoses are closed conduits, with sufficient head farmers can run them up adverse slopes and over obstacles. There are only very minor conveyance losses due to leaks. The water is easily placed exactly where the farmer intends it.

Water is delivered to the plants by bucket, by hose and by channels. The rates of delivery and the water applied per plant vary dramatically among these methods (Table 6.9). The flow from the hose and channel systems remains constant throughout the irrigation.

The gross delivery rate is more a function of the system design than of the energy or of skill or of the irrigator. The industry of the irrigator determines the amount per plant and uniformity of the delivery to the plants. Bucket irrigation extraction rates and the quality of the irrigations are directly dependent on the skill and energy of the irrigators. Bucket and hose irrigators deliver water at approximately ten liters per minute. Small channels deliver water three and a half times as quickly (34.9 l/m) and larger channels 23 times as fast (221.8 l/m).

Bucket and hose irrigators are far more frugal with the water they are applying per plant. They deliver, on average, 1.2 liters per plant, small channels carry seven times as much (9.2 liters per plant) and larger channels carry over 30 times as much (38.7 liters per plant). The number of plants watered per minute are similar for all of the methods, but the amount of water delivered per plant is much larger when channels are used.

From an engineering perspective, gravity feed, hose, and channel systems are very attractive. Most of these systems could be built with a few man-days effort. They are inexpensive to construct. If channels are used, no cash outlay is required, and if hoses are used, only a hose need be purchased. Those farmers who have as yet not built gravity feed systems, claiming construction is too much work, are simply not convinced (or perhaps concerned), that relatively small investments in infrastructure could save many hours of labour irrigating.

There are no hand pumps at any of the four sites. About half of the farmers at each site state that they would buy an inexpensive pump if one were available. No inexpensive off-the-shelf pumps are available, but custom made rope and washer pumps are being introduced in Lower Gweru and other selected communal areas. Rope and washer pumps are inexpensive and can be fabricated and maintained locally.

Rope and washer pumps or other small inexpensive hand pumps could be used to facilitate irrigation using wells and fish ponds of the existing design. Hand pumps, placed in shallow excavations, would have very little impact on the operation or organisational structure of the *bani* systems because they would not contribute to dramatic changes in the water table depths. Even though the lifts in most of the gardens are less two meters, scooping water from a well is arduous work. The delivery rates attainable with these pumps are several times those that even a practiced irrigator can achieve with a bucket and their introduction would decrease the time and effort required to irrigate a garden.

Most Zimbabwean *banis* are on the drier end of the spectrum of African wetlands. Farmers place emphasis on acquiring water to supplement rainfall and seepage. However, the majority of farmers have some problems with excess moisture which hinder production. Simple drainage, using shallow ditches, is often employed. Farmers also use two other techniques: rice cultivation and raised beds.

Before the imposition of European agricultural technology, rice was grown throughout Zimbabwe. It was cultivated in pits four to six feet in diameter, with sides raised to about a foot above ground. The pits, dug in swampy areas, were cropped two to four years without manuring, after which the farmers constructed new ones (Mundy, 1920).

Ancient examples of raised beds by agriculturalists cultivating wetter areas have been found throughout the world. While the date of their introduction in Southern Africa remains obscure, farmers were certainly planting on raised beds as part of their strategy to exploit *banis* before the arrival of commercial European agriculture (Whitlow, 1983, Trapnell, 1953).

The cultivation of rice and the use of raised beds are indigenous techniques used to make wetter areas productive. Although the construction of raised beds can be fairly labour intensive, neither of these techniques require technologies that are not adequately supported by local institutional infrastructure nor the purchase of extensive inputs. They can be adopted by the uninitiated in a gradual fashion as they become convinced that they work.

Early attempts by European farmers to 'reclaim' *banis* were grounded in their European experience. They excavated large open ditches through the center of the *banis*. The newly desiccated *banis* were initially productive, producing wheat for a few years. Shortly thereafter, the productivity of the soil deteriorated. Gullying initiated by the ditches, accelerated soil losses and interfered with the trafficability of the *bani*.

European methods were in vivid contrast to the more subtle methods of the modern gardeners studied. Excess moisture is dealt with by selecting water loving plants, constructing raised beds, refraining from planting, or constructing drainage ditches. Deep drainage structures are not part of their repertoire. The drainage ditches are almost always very shallow trenches designed to dry up very small areas. Undesired water is only channeled, at most, far enough to move it out of the plot. Outside of the garden, it either reinfiltrates or is picked up by another farmer's supply channel. Drains are almost never continuous structures removing water from several gardens to the perimeter of the system. Water quality in the *bani* is generally high and salination problems are not as yet a problem.

CONCLUSIONS

The analysis of the hydrology and operation of these systems lead to the following conclusions concerning *bani* groundwater management.

Bani irrigators are capturing adequate water supplies without hazard to the environment. The water supply to the *bani* and ultimately to the fluvial network is much more dependant on the land use choices in the upland areas than in the *bani*. In many instances, water use by gardeners is not dramatically higher than consumption by the undisturbed *bani* vegetation, and water unconsumed by the irrigators remains in the larger riverine watersheds. As these systems develop, the relative water supplies decrease, but water has yet to become the scarcest resource. The relative water supply for even the most intensively exploited of the four *banis* is approximately 1.5.

Bani irrigation is very efficient. A large portion of the crop water demand is extracted by the plants directly from the capillary fringe, leaving only a small fraction to be delivered by the irrigator. This saves the farmers labour that would otherwise be necessary to irrigate the crops. In addition, supplementary irrigation water is readily available using simple, inexpensive, low head, low power technologies: buckets, gravity feed systems, and hand pumps. However, deeper wells and mechanized pumps would be likely to reduce the overall efficiency and sustainability of these systems by lowering water tables below the capillary fringe, so that plants would no longer be able to take up water without extra irrigation applications.

Bani gardeners have the flexibility to tailor their gardening strategies to their own needs. The water supply is reliable enough for the farmers to time their production to provide for their household needs and to try to obtain favourable prices for the produce they sell in urban centres. In addition, *bani* farmers are able to customise their gardening practices as required by the moisture regime within their plots. The 'design' of a groundwater management system is dynamic. Farmers build, abandon, and renovate their infrastructure on daily, seasonal, and long term schedules.

Gravity feed and hand pump systems offer irrigators increased efficiency and reliability or water delivery. They require less energy and time to deliver water. Therefore, these innovations offer gardeners the opportunity to shorten the time they spend irrigating, freeing them to do other tasks. Under drier condition, gravity feed and hand pump systems linked to channels or hoses are more reliable than simple wells. Growing rice and planting on raised beds in the wetter areas of their garden allows farmers to exploit areas that are not easily drained and would otherwise lie fallow.

Generally farmers are free to operate as they wish without formal or even informal consultation with their neighbours. Farmers implement technologies to deal with the temporal and spatial variability found in their own gardens by lifting water from their wells, draining water from one area to another, planting appropriate crop varieties, constructing or customising raised beds, and using a variety of other subtle techniques. Farmers are customising their practices to optimise production in a variable environment. Variability is not eliminated, but accommodated.

The conservation ethos is well established in Zimbabwe and there is a reluctance to liberalise existing environmental legislation. Recent studies (Bell *et al.* 1987; Bullock 1992a) suggest that gardening does not inevitably jeopardize soil or water resources. The fears offered to justify rules banning *bani* cultivation appear to have been exaggerated.

This hydrologic analysis and the investigation of *bani* groundwater management leads to several favourable conclusion about these systems. *Bani* irrigators are capturing adequate water supplies without environmental hazard. They exploit the *bani* water supply in a balanced manner without mining the groundwater. These systems are easily managed. Farmers enjoy flexibility in the techniques they use and the timing of their crops and management methods to exploit a valuable resource. Farmers are able to improve their families food security and generate income in a sustainable fashion. Therefore, it is recommended that public policy should encourage farmers to develop *bani* land for crop cultivation. The conservation legislation now in force should be amended to regulate *bani* cultivation sensibly rather than forbid it.

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