

The Future of Terrace Farming in Yemen: A Development Dilemma

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ABSTRACT The country of Yemen, on the southwestern corner of the Arabian Peninsula, is one of the most extensively terraced areas in the world. There is a well-documented tradition of both dryland and irrigated farming over the past three millennia and much of the indigenous agricultural knowledge survives. Development efforts over the past two decades in the north of Yemen have focused on expansion of tubewell irrigation at the expense of the major land use on dryland terraces and traditional subsistence crops. Despite millions of dollars in aid, Yemen is far from agriculturally self-sufficient and its scarce water resource is rapidly being depleted. This article explores the relevance of indigenous Yemeni knowledge of agriculture and the environment for the future of terrace farming in the country. It is argued that farmer knowledge can contribute to sustainable production and can be grafted on to modern methods and technology. Within Yemen the existing community support networks and pride in national heritage would assist in a reinvestment effort for the existing resource of the terraces.

Farming is seldom associated with the Arabian Peninsula, but a long and successful tradition of agriculture developed in the southwestern corner known historically as Yemen. There is evidence for major irrigation systems in the first millennium B.C., most notably the renowned Marib dam, which was mentioned in the Muslim Quran.¹ Over the centuries Yemeni farmers transformed the rugged mountain slopes of the central cordillera into an extensive system of dryland terraces. A thousand years ago a major Yemeni scholar, Abu Hasan al-Hamdani, considered the dryland farming in his country one of the marvels of the world. An FAO mission to North Yemen in 1955 concluded that Yemen was one of the best terraced countries in the world at that time. Indeed, during the medieval period Yemen had one of the widest ranges of agricultural crops of any Arab land at the time.²

In May, 1990, the Republic of Yemen was formed of what used to be known as North Yemen (Yemen Arab

Republic) and South Yemen (Peoples Democratic Republic of Yemen).³ The modernization of agricultural methods in the North began about twenty years ago after a long and protracted civil war had ravaged the country's economy. Since this time there has been rapid growth in the North's Ministry of Agriculture and Fisheries, which has benefited from a variety of international and bilateral donor projects. The British introduced changes in the agricultural system of the South prior to 1967, when this part of Yemen was the British protectorate of Aden. Both North and South Yemen have laid great stress on returning to agricultural self-sufficiency, but in fact both countries have become more and more reliant on imported foodstuffs. Unlike their oil-rich neighbors on the peninsula, neither North or South Yemen has had the revenues to pay for increased food imports. Despite recent production of oil in the North, Yemen remains the poorest country on the Arabian Peninsula.

How is it that a country where nearly three-fourths of the population (now close to 11 million for North and South) are rural farmers cannot feed itself? In the North two decades of foreign assistance, including massive aid programs from other Arab countries and numerous well-funded agricultural projects, have yet to sprout a green revolution in a land known in the medieval period as "Green Yemen". In the South a state controlled economy had only a limited effect in improving production, while many of the educated South Yemenis left the country in recent years. There is no simple answer to this, nor is it merely a case of economic backwardness in an underdeveloped third world country. The long history of agriculture in the region and the obvious natural and human resources suggest that Yemen should be able to be self-sufficient in food production.

The development dilemma facing planners in Yemen is how to modernize a long-established system focused on subsistence production on dryland terraces in the highlands and seasonal flood irrigation along the major wadis.⁴ The traditional forms of agricultural production in Yemen utilized simple tools, limited animal draft power and relatively abundant household labor.⁵ The operating assumption of both the government and the donors has been that productivity can only be improved by a shift to irrigation in the coastal zone and valleys of the central highlands. Thus, in the North there was an extraordinary expansion of tubewells that in most cases has led to dramatic drawdowns of the water table. Along the major coastal wadis permanent dams have been built or planned, and a major new dam has been constructed above the site of the ruins of the famous Marib dam in eastern Yemen. In all of this, however, the extensive system of dryland terraces, representing the vast majority of Yemen's agricultural land, has simply been written off as too marginal and too dependent on household labor. Virtually no effort has been made through government programs to improve or at least stabilize existing terraces.

This article explores the future for dryland terrace farming in Yemen. Does the range of traditional farming in Yemen offer a basis for sustainable production alongside efforts to mechanize and irrigate with tubewells? The focus of my discussion is on the highland terrace system of the North, which is now in a seemingly irreversible state of decline. Having lived among Yemeni farmers for 18 months and having participated in a number of agricultural and environmental projects in North Yemen, I believe there is strong potential for building on the indigenous practices and knowledge of the environment in Yemen rather than assuming this mountainous land can somehow be forced into the mold of the wheat fields of Kansas.

From a strict economic perspective, it is obvious that dryland terrace farming is not nearly as productive as irrigated farming under appropriate mechanization. The government focus on the latest technology and new crops

is understandable, especially given the results of controlled field studies on donor-financed farm stations. The traditional staple of Yemen, sorghum in its almost infinite local varieties,⁶ is clearly not as profitable on the market as most new fruits and vegetables. Yet it is not the economic aspect alone that influences Yemeni farmers. The essential problem is how to get from here to there. The government estimates that about three-fourths of the land in the North is rainfed, with most of the rest based on traditional methods of spring or flood irrigation. Since most farmers own terraced land that can not be viably irrigated by pumpwells or utilize most forms of mechanization, what options do they have but to continue in the traditional manner? Even those who own or can buy relatively flat land appropriate for irrigation and mechanization must first find the necessary capital. Beyond these constraints, there is the issue of taste and preference. For example, sorghum and barley may not be priority crops of the Ministry of Agriculture and Fisheries, but they remain preferred foods for most of the population.

The overriding factor for the future of agriculture in Yemen, however, is neither economic or social. It has become increasingly clear to the government and donors that the accelerated destruction of the environment is the greatest single threat to increasing productivity in the manner advocated for the past twenty years. The bottom line for increasing production in a large part of the country is the availability of water. In the Sanaa basin, which includes the country's capital, irrigation may soon no longer be viable as the annual decline in the water table must now be measured in meters.⁷ Many farmers who have made major investments in sinking tubewells face loss of these investments as the water table continues to decline nationally and pumping costs are consequently increased. The loss of water is compounded by the loss of agricultural land as dryland terrace systems collapse through abandonment. The erosion of these terraces results not only in direct loss of the terrace, but also threatens irrigated land, especially along the upper and middle reaches of major coastal wadis. Once the terraces are destroyed and the soil washed away, farmers are literally forced off the land and must seek employment elsewhere.

Traditional Terrace Farming

The patchwork of terraces constructed on even the more isolated mountain slopes in Yemen is striking evidence of centuries of labor and ingenuity. Farmers here literally carved unusable steep slopes into productive land where agriculture would not normally occur. According to statistics from the 1983 Ministry of Agriculture and Fisheries census, about three-fourths of the North's 13,500 square kilometers of cultivated land is dry farmed, overwhelmingly as terraces. The common small, narrow terraces, when properly maintained, enhance water retention in the soil so that there is literally more crop *per*

drop than would occur on flat dryland plots. In addition, many of the terrace systems utilize slope runoff so that plots receive up to 40 percent more moisture than that from direct rainfall on the soil. In a study of traditional runoff harvesting in the Amran region of the North, Helmut Eger found that crop growth was possible even with as little as 150-300 mm rain per year.⁸ This explains in large part how agriculture was viable even in areas where rainfall data alone would not show sufficient precipitation. The use of slope runoff on terraces represents a resourceful ecological response to fluctuations in rainfall and the relative lack of suitable soil in much of the mountainous area.

The ingenuity of terrace construction is still quite visible in the Yemeni highlands, even from the limited perspective of a vehicle on one of the main roads in the country. Farmers considered a variety of factors in the local terrain in order to maximize water collection but not to the point of erosional stress. On steep slopes of more than 30° incline terraces are quite narrow, at times no more than a meter in width and supporting as little as one row of crop or trees. In more gentle slopes up to 15° incline the terrace may be up to eight meters wide. Few of these larger terraces exceed ten meters in length and most are much shorter. A slope is rarely continuous, so existing rocks and boulders are often incorporated into terrace walls. The rocks for terrace walls are generally available locally, but soil usually has to be brought in. In the past this had to be done by donkey load from alluvial fans far below the system.

Most terraces are constructed to take advantage of the local water regime. Where there is a spring or spring line, terraces will be located in clusters below so that a gravity-flow sequence can irrigate the system as a whole through a common channel network. In these springfed irrigation systems the water may descend through channels over a kilometer to the farthest plots. In the higher mountain slopes, where runoff harvesting is practiced, a group of terraces will be arranged so that excess flow will be carried off through the channels. Since farmers will not be present when the flooding occurs, it is important to allow for ample drainage of the flow in order to avoid erosion of the plots.⁹ Knowledge of the best location and size of both plots and channels is attained by experience. The principle is to use as much of the fast flow as feasible without jeopardizing the plot.

The location of terraces is also influenced by social factors. In the past, when time and labor were more available for household production, farmers often commuted considerable distances to field systems. This was especially the case for dryland crops such as wheat, barley, and sorghum that required relatively little care on a regular basis. However, the distance of fields from a village was dependent to a certain extent on the relative peace and security of the area. In the valley of al-Ahjur of the central highlands during the civil war of the 1960s many farmers were unable to cultivate distant fields

because of the presence of Egyptian troops on a nearby mountain. After the civil war in the North there was a nationwide drain of male labor as at least a third of the male workforce migrated for work outside the country. Not surprisingly, the more distant and marginal dryland terraces were more and more abandoned. While the basic dryland farming was left on the shoulders of women in many parts of the country,¹⁰ the process of terrace abandonment accelerated. It was not simply a shortage of manpower for working the terraces; the influx of cash remittances from male migrant workers and the availability of cheap grains and basic food supplies from the international market discouraged local production of food crops. By the late 1970s in the North it was cheaper to buy imported wheat in the market than to grow it.

The highland terrace system has for centuries been based on use of the scratch plow or ard pulled by donkey, bull, or camel. On narrow and inaccessible terraces fields had to be worked by hand with the traditional shovel-scoop and short-handled hoe. The basic subsistence crop was sorghum, which provided grain for bread and porridge and leaves and stalks for much-needed fodder. While most sorghum produced by a household was consumed at home, the fodder value of the plant represented a potential source of income in the market. On irrigated land, where sorghum plants may reach up to three meters, the market value of the leaves and stalks is quite high. Most Yemeni sorghum was grown during the summer, rotated on the higher dryland terraces with wheat, barley, or legumes in the winter. Legumes such as cowpeas were often interplanted with sorghum, a practice that in fact enriched the nutrient level of the soil.

The two major cash crops in Yemen's recent past have been coffee and qat (*Catha edulis*),¹¹ which can be grown on rainfed or irrigated land. Both of these stimulant plants arrived in Yemen from East Africa about the 14th century A.D. While Yemen began as the sole producer of the world's coffee, it has long since lost the market to the colonial coffee plantations that were created in Indonesia, Africa, and South America. The qat plant, the leaves of which produce a stimulant effect similar to fresh coca leaves, has only been marketed within the country. It has been the dominant cash crop in the North since the mid 1970s and the profits from cultivation of qat have allowed small farmers to survive in many areas and to expand on newly created well-irrigated plots. In areas where qat and other cash crops can be grown, often on irrigated terraces, farmers have maintained the terraces to a considerable degree. Ironically, the stimulant effect of qat production on the rural economy of the North has virtually been ignored by the government and donors, who view its cultivation and use as undesirable. In the South official government policy prohibited cultivation of qat in most parts of the country. Given the large government revenues from taxing qat production and marketing, it is doubtful that the Republic of Yemen will discourage its future production.

Despite periodic droughts and internal political disorders, the overall agricultural system of Yemen was adequate to meet the needs of the population over the centuries. Even in the dryland areas, which did not have the security of permanent irrigated land, this was not farming at the edge. However, it was very clearly farming for limited household needs rather than a market economy. The localization of the production system was due primarily to the difficulties of access in the highland region. As the modern republic introduces changes, it is no longer possible to continue with the traditional system. This is especially the case now that the Republic of Yemen is beginning to obtain oil revenues, although the population size and level of development will not allow the country to become a well-oiled welfare state like its neighbors on the peninsula.¹²

The Environment and Agricultural Development

In transposing the harsh natural terrain of the mountains into productive terrace systems, Yemeni farmers fundamentally altered the ecosystem centuries ago. This is not a case of pristine wilderness or open land being exploited by recent development. The environment of the terrace system is one in which the natural vegetative cover was removed to a large extent in the distant past, and in which some species dwindled or became extinct before the introduction of modern weapons. Traditional dryland farming was basically a sustainable practice, with Yemeni farmers attuned to conserving their resources of land and water. However, the highland terrace systems required proper maintenance not only to preserve the agricultural land of the terraces, but also to limit erosion of prime irrigated land. This is because the water regime in a given watershed became a balance between the control of land and water in the upper catchment area and the resulting flow of water in the major wadi systems descending to the productive coastal plain. It is now possible to measure the pace of destruction from the abandonment of highland terraces in a domino effect of erosion down a wadi. Because the centuries-old practices of water control are being set aside upstream, the yearly flooding of the wadis is becoming more and more destructive downstream and this threatens the future development of flood irrigation in the coastal region.

A major example of this destruction is along Wadi Zabid, once the most productive of the flood-irrigated areas in Yemen.¹³ This was the first of the coastal wadis to be developed for mechanized agriculture, primarily through the construction of several concrete dams. The focus of the Zabid project, funded by UNDP and the World Bank, was to increase irrigation supply in the coastal zone. Unfortunately, due to continuing disputes over water rights, the project was unable to develop an appropriate channel network to fields within the wadi system. Thus, the expectations for improved production have yet to be fulfilled.

No thought was given previously to the possible

effect of terrace abandonment in the upper reaches of Wadi Zabid, despite some fairly detailed studies conducted by the British in the Dhamar region of the central highlands. In the late 1960s there was still a relatively dense acacia cover in the upper catchment, but this has largely been stripped now due to improved access to the area and constant demand for fuelwood in Yemen. The result is a barren, soil-less escarpment with major sheet and wadi erosion down the length of the system. In effect, a large gravel glacier is descending Wadi Zabid and washing away once profitable land in the upper and middle reaches of the wadi. According to estimates from a recent physical survey of Wadi Zabid from top to bottom, perhaps 70 percent of the cultivated land in the upper reaches of Wadi Zabid has now been destroyed.¹⁴ To make matters worse, gravel and silt carried by the floods are now accumulating in large amounts downstream and require costly silt removal efforts at the major dams along the wadi. According to engineers involved with the Zabid project, the land irrigated from the major dams has been decreasing in recent years. The current upstream erosion will result in even less efficiency in a system originally built as a model for the rest of the country.

The ecological devastation along Wadi Zabid is exacting major economic and social costs on local residents, especially in the upper catchment area. In a documentary film recently produced on the area for the Arid Lands Initiative, based in England, one group of farmers along Wadi Zabid was interviewed next to what used to be their land. Due to increasingly destructive floods resulting from abandoning of the terrace systems upstream, some twenty farmers lost about seven-eighths of their land in the past decade. This happened in one 500 meter stretch of the wadi, with half of the damage in the past two years. The farmers estimated the loss of income from this destruction of their land at about \$75,000. Similar destruction has been reported along the wadi to within 20 kilometers of the coast. The full extent of the damage has not yet been determined, nor is it likely to be in the near future. Yet for these farmers and many others in similar situations their most precious possession, the land on which generations of Yemenis have farmed, has literally been washed away. It is not a matter of starting over, obtaining a government loan or new technology, or more efficient methods of production; there is nowhere to go once the land has been lost.

Throughout Yemen's history there has always been destruction of agricultural terraces due to political or economic upheavals. What is unique about the current destruction is the rapid pace of change. The building up of an infrastructure greatly stimulated the rural economy and has been a boon for farmers who now find it easier to market their crops. Yet the same roads and services that signal progress also create unprecedented stress on the environment. One of the most critical problems brought on by improved access and quality of life in the

rural areas is the skyrocketing demand for fuelwood, the primary energy source for the traditional clay tannur oven and for charcoal braziers used in virtually every household. The limited tree cover throughout Yemen has been declining at an alarming rate. A recent World Bank energy assessment for the North concludes that fuelwood resources will be depleted in the next 10-15 years.¹⁵

Sustainable Development: Investing in the Indigenous Tradition

The unification of North and South in the new Republic of Yemen has necessarily been a time for transition in government policy on all levels, especially concerning agricultural development. It is now evident that no agricultural policy will be viable in the country unless it comes to terms with the rapid environmental degradation. Given declining water tables in virtually every part of the country, unchecked cutting of tree cover and the erosion problems linked to abandonment of highland terraces, future production over the long run must be within the obvious constraints of the country's natural resources. Agricultural self-sufficiency can remain the primary goal, but the methods of achieving this must be re-evaluated.

If it is no longer even a short-term option in some sections of the country to expand tubewell irrigation, there is little choice but to consider improving dryland and seasonal flood systems. The essential issue is how to assist the vast majority of Yemeni farmers who are still farming in more-or-less traditional fashion. The end goal should not be maximization of production *per se*, but rather improving the production context so that it is economically viable for farmers to remain on the land. Unfortunately, the apparatus put in place by donor-financed government initiatives has neither the information nor the expertise to switch to a sustainable agriculture program. To make matters worse, the expectations of Yemeni farmers have been raised unrealistically by at least two decades of well publicized promises about the benefits from mechanization and expanded irrigation.

What would it take to reinvest in the terrace system? The priority need in many parts of the highlands is for terrace stabilization, since previous abandonment has already resulted in considerable erosion damage. From a technical point of view, one option is to encourage direct seeding of high-yield agroforestry crops. In addition to assisting in soil retention in the terraces, this would provide a crop well suited for the rural market. However, the choice of varieties must be carefully studied, so as not to adversely affect the existing plant communities and to meet the interests of local people.¹⁶ Similarly, there is a need for more fodder crops in Yemen. Research by the Dutch at the Range and Livestock Improvement Project in Dhamar has resulted in several varieties suitable for the local terrace systems.¹⁷ It is also worthwhile considering improving existing crops with market potential. The most obvious example is qat, which has proven to be

the most consistent cash crop for highland farmers for more than a decade.¹⁸ The continued cultivation of sorghum, a crop with extraordinary genetic diversity in Yemen, must also be addressed. Because many rural Yemenis still consider sorghum a staple, it will be cultivated for years to come regardless of profitability.

The technical solutions to stabilizing the terraces and finding appropriate crops are not simple, but they are realizable. Perhaps the most crucial factor affecting the future of terrace farming in Yemen is the willingness of rural Yemenis to remain on the land and farm. The shortage of household agriculture labor, witnessed in most regions during the past two decades, is no longer the case. The return of thousands of Yemeni workers from the Gulf and Saudi Arabia in the past year is probably an irreversible process. There are few opportunities for expansion of jobs in Yemen's industrial or service sectors, nor does the government currently have the revenues to assist the returning workers with compensation. Even those men who have not personally been involved in farming in the past decade or so may have little choice but to return to the fields.

In the heyday of Yemeni remittances from workers abroad, the rural sector was greatly stimulated by a steady cash flow. This allowed Yemenis to literally build up their own infrastructure and is one reason for the success of the cooperative movement in the country. Thus, it was possible to hold on to the land with remaining household members doing what they could. In effect the remittances subsidized the rural production system. Profitability on the farm was not as crucial when the main income was derived from a male member working abroad. The widespread availability of cash stimulated local production of cash crops for the rural sector, especially the lucrative qat leaves. And what could not be grown could be purchased on the market relatively cheaply due to past import policies in the North. Once the remittance wealth is removed from the equation, as noted over a decade ago by Jon Swanson,¹⁹ even the existing subsistence production is inadequate. The Republic of Yemen now has oil revenues to offset to some degree the economic downswing in the country, but it does not have the governmental structure nor sufficient revenues to create another welfare state along the lines of Saudi Arabia or the Gulf States. The return of Yemeni workers has the potential for a major blow to the rural sector of Yemen with repercussions throughout the economy.

Although attitudes can change rapidly, it can still be argued that most rural Yemenis still prefer to live where they are. Considerable investments have already been made in maintaining or building new homes in the countryside and building up the necessary infrastructure. The overcrowding in the capital of Sanaa and some other large cities serves to strengthen the will of many families to stay on the land. The critical test of the continuing interest in living on the farm will come as the current generation emerging from the expanded rural school

system comes of age. Will the expectations raised in the education process and the lure of city life entice sufficient numbers of rural youth off the farm even though jobs are limited or virtually non-existent in the cities or abroad?

There are two factors that add a positive note to the possibility of sustainable agriculture in Yemen. The first is the long-recognized community support for self-development.²⁰ In tribal areas this occurs in the traditional tribal mechanisms for mobilizing rural tribesmen for action. Even in areas where the tribal system is relatively weak, the concepts of community self-help and local participatory involvement in government have been used to mobilize villagers. Local development councils in the North have in some cases taken action to prohibit further cutting of trees and repair erosion damage to roads. These political mechanisms, long encouraged by the government in the North, could be used for rebuilding terraces and maintaining existing terrace systems.

Another resource for reinvesting in the terrace system is the pride Yemenis take in their history. The heritage of the country not only extends to the civilizations of pre-Islamic South Arabia, but also includes the cumulative knowledge of generations of Yemeni farmers. The physical presence of elaborate terrace systems points to a range of indigenous knowledge developed over centuries of experience for each locality. This lore is not simply a curiosity to be documented in academic journals, but a living tradition. In fact, Yemen may be one of the last countries in the Middle East where it is still possible to find traditional agricultural practices relatively unaffected by technological or economic change. Is it not better to build on relevant local knowledge of the environment and how to grow traditional crops than to wipe the slate clean with unrealistic expectations or inappropriate technologies?

My experience living among highland Yemeni farmers over a decade ago resulted in a great appreciation for their overall abilities to extract production out of an inhospitable environment. It is hard to measure the "feel" farmers often have for positioning a plot to receive slope runoff or in planting a seed at a certain depth based on the amount and timing of rainfall in a given locality. It is also hard to translate the relevance of a conversation between old men about whether a certain star was visible and thus the planting should begin in a section of the valley. The point is that these farmers often have an extraordinary sensitivity to their local environment given the information available. Some of the local knowledge may be more relevant in a given context than that learned by a Yemeni student abroad in an agricultural degree program. But the most important point is that this sensitivity to sustained production within the limits of the natural resources be preserved.

The future of farming in Yemen is ultimately not an agricultural issue, for the fact that some sort of farming will continue is obvious. The real issue is the effect of

inevitable social and economic change on the willingness of farmers to stay on the land. The natural beauty of the landscape and the freedom of rural lifestyle may not be as significant as the need for household income, but these and other deeply rooted values are relevant to the future of farming here. The most critical issue at present is whether or not there will be any land to stay on. The widespread abandonment of highland terraces has already destroyed much productive land, and the limited water supply in the country will not allow sufficient expansion of tubewell irrigation beyond the immediate future. It is certainly worth the effort of building on the long tradition of indigenous agricultural knowledge and adapting what is relevant to a sustainable production system. Otherwise, it may be the future of the country itself that may be eroded away.

Notes

1. This was constructed in the 6th century B.C. at the site of the capital of Saba or Sheba, a state that flourished on the spice trade of antiquity. A maximum of 9600 hectares of land were irrigated by this dam. The dam collapsed in 575 A.D., about the time that the prophet Muhammad was born. For more information on the Marib dam, see Jurgen Schmidt, "The Sabaean irrigation economy of Marib," in Werner Daum (editor), *Yemen. 3000 Years of Art and Civilisation in Arabia Felix*, pp. 55-62. Innsbruck: Pinguin-Verlag.
2. A rich collection of agricultural texts exists from the Rasulid dynasty in Yemen during the 13th to the 15th centuries A.D. These are described in D.M. Varisco, "Medieval Agricultural Texts from Rasulid Yemen," *Manuscripts of the Middle East* (Leiden) 4:150-154, 1989. For translations of some of these texts, see: R.B. Serjeant, "The Cultivation of Cereals in Medieval Yemen," *Arabian Studies* (Cambridge) 1:25-74, 1974; D. M. Varisco, "A Royal Crop Register from Rasulid Yemen," *Journal of the Economic and Social History of the Orient* (Leiden), 34: 1-22, 1991; D. M. Varisco, *Medieval Agriculture and Islamic Science. The Almanac of a Yemeni Sultan*, University of Washington Press, in press.
3. This article is based on my experience in North Yemen over the past twelve years. There are similar environmental problems in South Yemen, but the economy there was under a socialist regime until the unification in 1990.
4. The term *wadi* refers to a major watercourse that only swells during the rainy season; there are no permanent rivers in Yemen apart from small streams fed by springs. The two major rain periods in Yemen are in spring and late summer. Most of the precipitation is dropped in the southern part of the central highlands, where up to 1800 mm can fall in a year. For an excellent description of flood irrigation in Yemeni *wadis*, see: Abdullah Maktari, *Water Rights and Irrigation Practices in Lahj*. Cambridge: Cambridge University Press, 1971; R. B. Serjeant, "Some irrigation systems in the Hadramaut," *Bulletin of the School of Oriental and African Studies* 27:33-76, 1964; and, D. M. Varisco, "Sayl and Ghayl: The Ecology of Water Allocation in Yemen," *Human Ecology* 11:4:365-383, 1983.
5. There is no overall discussion of traditional agriculture in Yemen, although information is available in several ethnographic studies and development reports. A brief survey of agriculture in the earlier part of this century for the North can be found in FAO, *Report of the FAO Mission to Yemen*. Rome: FAO, 1960; for the South, see Great Britain Admiralty, *Western Arabia and the Red Sea*. London: Naval Intelligence Staff, 1946 (B.R. 527). A thorough review of contemporary agriculture from a geographical perspective is provided by Horst Kopp, *Agrogeographie der Arabischen Republik Jemen*. Erlangen: Erlanger Geographische Arbeiten, Sonderband 11, 1981. The issue of land use and land tenure in Yemeni agriculture is explored in D. M. Varisco, "Land Use and Agricultural Development in the Yemen Arab Republic," in M. Salem-Murdoch and M. Horowitz (editors), *Anthropology and Development in North Africa and the Middle East*, pp. 292-311. Boulder: Westview Press, 1990. For agricultural tools, see D. M. Varisco, "The Ard (Plough)

- in Highland Yemeni Agriculture," *Tools and Tillage* (Copenhagen) 4:3:158-172, 1982. For springfed irrigation, see Martha Mundy, *Land and Family in a Yemeni Community*. Ph.D. Dissertation, Cambridge University, 1981, and D. M. Varisco, *The Adaptive Dynamics of Water Allocation in al-Ahjur, Yemen Arab Republic*. Ph.D. Dissertation, University of Pennsylvania, 1982. For dryland terrace farming, see: Genevieve Bedoucha, "Une antique tradition chez les hommes de tribus des hauts plateaux yemenites: La culture du sorgho," *Techniques et Culture* 8:1-68, 1986; Walter Dostal, *Egalitat und Klassengesellschaft in Sudarabien*. Vienna: Wiener Beitrage zur Kulturgeschichte und Linguistik, Band XX, 1985; Paul Dresch, *Tribes, Government, and History in Yemen*. Oxford: Clarendon Press, 1989; Andre Gingrich and Johann Heiss, "Beitrage zur Ethnographie der Provinz Sa'da (Nordjemen)," *Sitzungsberichte Oster. Akad. d. Wissenschaften, Phil.-Hist. Klasse*, Band 462, 1986; Richard Tutwiler and Sheila Carapico, *Yemeni Agriculture and Economic Change*. Sanaa: American Institute for Yemeni Studies, 1981; Horst Vogel, "Terrace Farming in Yemen," *Journal of Soil and Water Conservation* 42:18-21. There is useful information on dryland farming in Richard N. Tutwiler, *Tribes, Tribute, and Trade: Social Class Formation in Highland Yemen*. Ph.D. Dissertation, State University of New York at Binghamton, 1987; however the pedantic Marxist interpretation adopted in this thesis is ill-suited for the North Yemeni context. Important regional data on agriculture are also available in Hans Steffen et al., *Final Report on the Airphoto Interpretation Project of the Swiss Technical Co-operation Service*. Berne, 1978.
6. In the late 1970s USAID sponsored a project to improve local sorghum varieties, but this ended in failure because the government found the project too focused on research and lacking in tangible results. For a discussion of traditional sorghum farming in Yemen, see D. M. Varisco, "The Production of Sorghum (Dhurah) in Highland Yemen," *Arabian Studies* 7:53-88, 1985.
 7. In 1955 an FAO team noted that groundwater at Sanaa could be reached at 20 meters depth. The level in the main well field for Sanaa's public water supply is now below 180 m and some of these wells are dry. A Dutch advisory team to the Department of Hydrology in the Ministry of Oil and Mineral Resources notes that irrigation is probably no longer viable in the Sanaa area and that in the al-Beidha area to the southeast the irrigation supply may be exhausted in three years. At present rates of exhaustion, the groundwater of the Marib area, site of a major new government irrigation project, may be depleted in 20-40 years. Cases have been documented of wells being drilled for irrigation to a depth near 1000 meters in parts of the highlands. (This information was provided by members of the Dutch team in late 1989. They are in the process of compiling a hydrographic profile of all of North Yemen)
 8. This is discussed in Helmut Eger, "Rainwater Harvesting in the Yemeni Highlands," in H. Kopp and G. Schweizer (editors), *Jemen Studien* (Wiesbaden) 1:146-169, 1984. See also his "Runoff Agriculture. A Case Study about the Yemeni Highlands," *Jemen Studien* 7, 1987.
 9. This is a major difference from seasonal flood irrigation along the main wadis, where the farmers are usually present to divert the flow to their fields when the flood level is sufficiently high. As a result there is a greater need for coordination between individual irrigators in a flood irrigation system than in a runoff harvesting system or springfed irrigation system.
 10. The best discussion of women's role in Yemeni agriculture is by Najwa Adra, *The Impact of Male Migration on Women's Roles in Agriculture in the Yemen Arab Republic*. (unpublished report prepared for FAO in 1983). Information is also available in Cynthia Myntti, *Women and Development in Yemen Arab Republic*. Eschborn: GTZ, 1979.
 11. The best survey of qat in English is by Shelagh Weir, *Qat in Yemen. Consumption and Social Change*. London: British Museum Publications, 1985. A study of the effects of chewing qat leaves is provided by John Kennedy, *The Flower of Paradise. The Institutionalized Use of the Drug Qat in North Yemen*. Dordrecht: Reidel, 1987. For a social analysis of the use of qat, see D. M. Varisco, "On the Meaning of Chewing: The Significance of Qat (*Catha edulis*) in the Yemen Arab Republic," *International Journal of Middle East Studies* 18:1:1-13, 1986. I have argued for the development potential of qat production in my "The Qat Factor in North Yemen's Agricultural Development," *Culture and Agriculture* 34 (Spring): 11-14, 1988.
 12. For a perspective on the implications of oil revenues for Yemen, see Robert D. Burrows, *The Yemen Arab Republic. The Politics of Development, 1962-1986*. Boulder: Westview Press, 1987. pp. 133-152. Recent events of the 1990-91 Gulf Crisis have greatly increased Yemeni oil revenues, especially since it is exported from the western shore of the peninsula.
 13. Wadi Zabid figures prominently in medieval agricultural texts. The agricultural cycle of this wadi in the medieval period is described in D. M. Varisco, "Agriculture in Wadi Zabid during the Rasulid Era," in Edward Keall (editor), *Preliminary Report on the City of Zabid*. Toronto: Royal Ontario Museum, in press. The major survey of the wadi for development purposes can be found in the multi-volume UNDP report by Tesco, et al., *Survey of the Agricultural Potential of the Wadi Zabid, Yemen Arab Republic*. Budapest, 1971-1973. For an overview of agricultural development in the coastal region, see Martha Mundy, "Agricultural Development in the Yemeni Tihama: the past ten years," in Brian Pridham (editor), *Economy, Society and Culture in Contemporary Yemen*. London: Croom Helm, 1985.
 14. This is based on research of Anthony Milroy and reported in D. M. Varisco, J. P. Ross and A. Milroy, *Biological Diversity Assessment of Yemen*. Cambridge: International Council for Bird Preservation, 1990. The visual impact of the destruction can be seen in the documentary film called *Hanging Gardens of Arabia*, directed by Andre Singer and produced for The Arid Lands Initiative, 72A Bridge Lane, Hebden Bridge, West Yorkshire HX7 5TE, England.
 15. See Andrew Millington, *YAR: Household Fuel Marketing Study, Phase 2. Woody Biomass Resource Assessment. Final Report*. UNDP/World Bank Energy Sector Management Program, 1988. This report estimates that 90 percent of rural energy consumption in residences is based on local fuelwood. The Ministry of Agriculture and Fisheries has been active in promoting tree planting, but this has not kept pace with the loss of tree cover.
 16. For an informative account of the role of farmer interest in a reforestation project in the North, see Charles F. Swagman, "Doing Development Anthropology: Personal Experience in the Yemen Arab Republic," in M. Salem-Murdock and M. Horowitz (editors), *Anthropology and Development in North Africa and the Middle East*, pp. 279-291. Boulder: Westview Press, 1990.
 17. This project was conducted by DHV Consulting Engineers (Amersfoort, The Netherlands) and has produced numerous publications. Of particular relevance is Chrisje van Schoot, *From Recommendation to Acceptance. The Dissemination of the Atriplex Message in the Yemen Arab Republic*. Dhamar, 1989. (Project Communication No. 31) Also of relevance is a report on the conservation potential of traditional rangeland reserves; see J. J. Kessler, *Mahjur areas: Traditional Rangeland Reserves in the Dhamar Montane Plains (YAR)*. Dhamar, 1988. (Project Communication No. 16). See also Klaus Muller-Hohenstein et al., "Applied Vegetation Studies in the Yemen Arab Republic: Range Management and Terrace Stabilisation," *Catena* 14:249-265, 1987.
 18. The issue of qat cultivation and use in Yemen is a sensitive issue. In the North the tendency was to ignore the role of qat in the economy, while the South virtually prohibited its use. My experience with farmers in the highland valley of al-Ahjur indicates that qat profits are often invested in expanding production of other crops. See note 11.
 19. Jon C. Swanson, *Emigration and Economic Development: The Case of the Yemen Arab Republic*. Boulder: Westview, 1979. See also Shelagh Weir, "Labour Migration and Key Aspects of its Economic and Social Impact on a Yemeni Highland Community," in R. Lawless (editor), *The Middle Eastern Village. Changing Economic and Social Relations*, pp. 273-296. London, 1987.
 20. There is a sizeable literature on the cooperative movement within the North, although much of this is now out-of-date. For a review, see Sheila Carapico, *The Political Economy of Self-Help: Development Cooperatives in the Yemen Arab Republic*. Ph.D. Dissertation, State University of New York at Binghamton, 1984. An excellent first-hand account of the role of local development associations in rural Yemen is provided by Charles F. Swagman, *Development and Change in Highland Yemen*. Salt Lake City: University of Utah Press, 1988.