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FINAL REPORT

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"IS DROUGHT FOLLOWING THE PLOW IN LESS-DEVELOPED COUNTRIES?"

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EXECUTIVE SUMMARY

The overriding project purpose was to determine to what extent *drought* (defined socio-economically) is increasing in the developing world as a result of population pressure, the scarcity of viable new cropland, environmental degradation, and other major factors. This project was conducted in Morocco, a representative drought-prone developing country. Key objectives were to contribute to the emerging frontier of theory on the human dimensions of global environmental change and to develop an efficient, cost-effective methodology for LDCs to use to assess and monitor their drought hazard. Research was conducted at three different levels of resolution: local, regional, and national. At the local level, project researchers administered a series of interviews to 335 rural households in three different regions of Morocco to learn more about farming practices that have possibly increased vulnerability to drought and to understand "grass roots" drought coping strategies. At the regional level, researchers examined crop production statistics, meteorological data, and census data and also analyzed Landsat MSS imagery of the study-site areas. At the national level, they analyzed NOAA/AVHRR weather satellite data and examining national policies. In addition to research activities, key Moroccan personnel associated with the project underwent training in GIS and remote sensing technology, including hands-on training developing a GIS database for drought and other environmental analysis in Morocco. Project research at both the micro- and macro-scales clearly demonstrated that the drought hazard in Morocco has gradually been increasing—primarily due to the following two processes: (1) expansion of cereal cultivation to drought-prone rangeland; and (2) reduction of fallow.

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"IS DROUGHT FOLLOWING THE PLOW IN LESS-DEVELOPED COUNTRIES?"
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1.0 RESEARCH OBJECTIVES

The overriding objective of this project was to test the "drought follows the plow" hypothesis, which asserts that growing population pressure, the scarcity of viable new cropland, environmental degradation, and other key factors are forcing many developing countries to expand agricultural production to marginal low-rainfall areas, causing them to become increasingly vulnerable to drought. This project was conducted in Morocco, a representative drought-prone developing country. Specific objectives of the project were to refine or reformulate the drought-follows-the-plow hypothesis to increase its explanatory power; to contribute to the emerging frontier of theory on the human dimensions of global environmental change; and to develop an efficient and cost-effective methodology for LDCs to use to assess and monitor their drought hazard.

1.1 Research Hypotheses

The "drought follows the plow" hypothesis was originally formulated by M.H. Glantz, Head of the Environmental and Societal Impacts Group at the National Center for Atmospheric Research (Glantz and Katz 1984; Glantz 1990, 1992). Glantz is a leading authority on drought and desertification (see Glantz 1976, 1977, 1987, 1992). His hypothesis represents an insightful inversion of the "rain follows the plow" myth that figured prominently in the settlement of the American Great Plains (Kollmorgen 1935).

Glantz developed the drought-follows-the-plow hypothesis to explain the drought that devastated the West African Sahel during the late 1960s and early 1970s. According to this interpretation, the two decades prior to the onset of drought had been relatively wet, which encouraged peasant farmers to expand cultivation into rangeland on the margins of the Sahara. This northward expansion dislodged pastoralist groups. In turn, they shifted their herds north, where unusually high levels of rainfall produced ample forage, even in areas that were normally desert. Herds grew steadily larger. As this favorable period continued, more and more peasant farmers encroached on rangeland. In 1968, however, a severe drought struck. By 1973, over 100,000 humans and 12 million livestock had perished (Glantz and Katz 1984; Glantz 1990). The drought gave rise to widespread fears that the Saharan desert was expanding. However, what was occurring was simply a return to normal weather on the desert's margin.

A key characteristic of the drought-follows-the-plow hypothesis is its perspective of drought as primarily a socioeconomic phenomenon. According to this perspective, the only drought that really matters to society is drought in which there is a shortage of

water *to sustain established human activities* (Wilhite and Glantz 1985; Wijkman and Timberlake 1984; Susman et al. 1983). Thus, low rainfall levels that are not presently perceived as drought may eventually represent a "natural disaster" if a region develops in such a way that the demand for water exceeds the normally available supply.

The drought-follows-the-plow hypothesis has profound implications for the developing world. High population growth rates in most developing countries are placing unprecedented pressure on existing resource bases. Unfortunately, most developing countries lack viable new cropland to help relieve population pressure. This shortage, often combined with political, environmental, economic and other factors, is forcing farmers to expand into marginal areas--areas with defective soils, excessive slopes, or *deficient rainfall*. The marginal areas put under the plow are not only prone to erosion and desertification: many are also more vulnerable to drought. According to the drought-follows-the-plow hypothesis, one can anticipate an increase in future incidents of "drought" in the developing world.

This PSTC-funded research project differed from most previous natural hazards studies in two important ways:

- First, this research focused on the relativity of the drought hazard. Since the genesis of natural hazards research in the early 1960s, most researchers have viewed natural hazards as "extreme" but objective events within natural geophysical processes (Hewitt 1983). Within this "dominant view," hazards are usually treated as independent variables. The sense of causality typically runs from the extreme event or process to its societal impacts. Nature is seen to possess the initiative, and to determine when and where calamity will strike. Although it is acknowledged that the societal context can mitigate or amplify a given natural hazard, consideration of such relativity has usually been relegated to a peripheral position within the research agenda or has been ignored altogether. This field has concentrated primarily on: (a) differential perceptions of objective natural hazards, and (b) adjustments to these hazards (Hewitt 1983; Mitchell 1974, 1984, 1989, 1990; O'Riordan 1986; White 1973; Whyte 1986).

  By contrast to this dominant tradition, the present project emphasized the relativity of natural hazards to their societal contexts. According to this project's perspective, natural hazards are not objective events or processes that can be treated as independent variables since they depend on human activities for their existence. The essence of the "drought follows the plow" hypothesis is its assertion that human activities convert latent environmental hazards into actual hazards. As Mitchell aptly puts it, "hazards are not; they become" (1990: 132). Drought doesn't occur simply because of reduced rainfall. The essential criterion is a shortage of rain to sustain established human activities. "Drought" doesn't occur in the middle of a desert. However, it can occur on desert margins when, during periods of higher-than-normal rainfall, pastoralists and cultivators establish themselves on these margins. In such a situation, a return to normal

rainfall conditions represents "drought" and can precipitate disaster, as it did in the West African Sahel in the late 1960s and early 1970s.

- A second and related way that the present research differed from most previous hazards research is through its explicit focus on the socioeconomic context of a given natural hazard. Specifically, it examined drought within the context of contemporary economic development and social change in Morocco, taking account of all major factors that have combined to create the drought hazard in this country. These include environmental conditions, government policies, land-tenure systems, land-holding patterns, agricultural technology, and differential access to resources. This research also demonstrated how the drought hazard in Morocco interlocks with and is reinforced by other major societal problems, such as the colonial legacy, longstanding government neglect of dryland cereal cultivation, rapid population growth, land fragmentation, and environmental deterioration.

This project tested the validity of the "drought follows the plow" hypothesis by comprehensively analyzing Morocco's drought history during the past two decades. Specifically, research tested the hypothesis that farmers in Morocco have been progressively increasing their country's vulnerability to drought through expanding cereal cultivation to low-rainfall areas and reducing acreage left in fallow. Research focused on the following *key variables*: the spatial and temporal patterns of agricultural expansion and intensification (i.e., reduction of fallow); the political, demographic, economic, governmental, and environmental factors behind this expansion and intensification; the socioeconomic impacts of specific drought episodes and how these impacts have changed over time; and farmer coping strategies in response to drought.

1.2 The Study Area

Morocco represented an excellent setting for a case study on the "drought follows the plow" hypothesis. Drought is an endemic natural hazard in this North African country (Swearingen 1987a, 1987b, 1992, 1994, 1996). Morocco is situated on the southern *margins* of mid-latitude storm systems arriving from the northern Atlantic. As a result, both the timing and total amounts of rainfall are extremely irregular. Climatic variability introduces a high degree of risk in rainfed agriculture. Furthermore, precipitation levels are generally insufficient for prosperous rainfed agriculture throughout most of the country. Since 1960, drought has struck on seven different occasions, producing poor to disastrous harvests during ten crop years. Seven of these drought years have occurred since 1980.

Morocco is especially vulnerable to drought because rainfed cereal cultivation (primarily wheat and barley, the country's staple food crops) accounts for approximately 85 percent of Morocco's cropland and well over 90 percent of its farmers. Drought sharply reduces both cereal yields and cereal hectarage, causing food production to plummet. Typically during a drought year, the Moroccan economy suffers major contraction. Cereal imports rise dramatically, food prices soar, food shortages develop,

malnutrition becomes more extensive, peasants abandon their land and flock to the cities, herds perish for lack of forage, and soil erosion and desertification increase. Drought is Morocco's leading natural hazard (Swearingen 1992, 1994, 1996). This study is the first comprehensive analysis of the drought hazard in Morocco and the degree to which this hazard has been changing over time.

2.0 METHODS AND RESULTS

Project research was conducted at 3 different levels of resolution: local, regional, and national:

2.1 Local-Level Field Research

2.1.1 Methods Employed in Local-Level Field Research

At the local level, project researchers conducted intensive interviews in three different regions of Morocco: the Chaouia, the Chichaoua, and Maroc oriental. In each region, a study site was selected which covered approximately 100 square miles and included several villages. All study sites were in regions where the main drought-related intensification processes were known to have taken place, including extension of cultivation to marginal, low-rainfall areas and increases in the cultivated area at the expense of fallow. These sites were selected on the basis of the following characteristics:

- *Environmental characteristics.* The concern was to identify research sites that were not only drought-prone but also differentiated along a gradient running from sub-humid through semi-arid to arid. The Chaouia site is sub-humid; Maroc oriental is semi-arid; and the Chichaoua site is arid.

- *Demographic factors.* Here the concern was to identify research sites with different levels of population pressure (low vs. high population pressure) in order to understand different intensities in landuse and different vulnerability levels in terms of exposure to drought. The Chaouia site is distinguished by relatively high population densities (80 to 120/km^2) as opposed to Maroc oriental and particularly the Chichaoua site, where densities are relatively low (30 to 40/km^2).

- *Historical considerations.* Historical considerations included factors such as *when* sedentarization of nomads had taken place. Researchers acknowledged that related to the "drought follows the plow" hypothesis is a long-term generalized transition of traditional rural communities in Morocco from extensive pastoralism and accompanying nomadic patterns into settled and more intensive farming systems. This trend is closely related to demographic pressure and has interesting correlations with vulnerability to climate variability.

Dr. Bencherifa, the collaborating foreign investigator, directed a Moroccan team of fellow professors and graduate students who interviewed farmers about farming practices and drought-coping strategies. This team selected a total of 335 households or production units for interviews: 194 in the Chaouia, 101 in the Chichaoua, and 40 in Maroc oriental. Interviews consisted of a series of six questionnaires, which were administered *orally* to the same household units over a period of approximately twenty months, from September 1992 to May 1994.

The interview protocol was intended to allow for capture of information about dynamic responses of producers to specific climate conditions, including both drought and good rainfall years. By coincidence, this survey covered periods of highly variable weather. The agricultural years 1991-1992 and 1992-1993 were characterized by extreme drought conditions following an exceptionally rainy year during 1990-1991 (for which data was also gathered). By contrast, the agricultural year 1993-1994 was unusually humid. These highly variable conditions allowed the project researchers to observe first-hand and directly interrogate farmer responses to drought, and also to witness and interrogate farmer responses to abundant rainfall conditions.

The first survey, conducted in September 1992, consisted of questions designed to gather fundamental socioeconomic data for each study site and production unit within the sample, such as household size and composition, land size and tenure, herd size and composition, and production resources (including machinery, draft animals, and equipment). Subsequent surveys addressed strategies and responses related to drought and other dynamic environmental conditions. Strategies and responses of interest included land use, livestock management patterns, allocations of labor, and alternative income-generating activities. The successive surveys enabled the researchers to track both structural and process-related changes between questionnaires and over the entire survey period. A summary of results from these surveys follows.

2.1.2 Results From Local-Level Field Research

In all three study-site areas, it is clear that *rainfall variability is well accounted for in production strategies*. The pastoral-nomadic and historical-cultural backgrounds of the communities in these study areas provides, in effect, a body of memories which allows drought to be regarded as a normal rather than an exceptional event. Farmers expect periodic drought and plan for it in their production strategies. Unfortunately, these drought-coping strategies rapidly begin to lose their effectiveness when drought events last more than one year at a time. These strategies have also been weakened by increasing population pressure and the resulting more intensive use of agricultural land and reduction of fallow. In addition, increasing inequalities between producers (a result of the unequal penetration of market-oriented farming practices), has increased the vulnerability to drought of the poorest farming households relative to more prosperous farmers.

The field surveys enabled the research team to **make several important generalizations** relevant to the "drought follows the plow" hypothesis and farmer drought-coping strategies:

⇒ ***Livestock raising is a basic component of farming systems*** in all three study regions and is a fundamental feature of farmers' survival strategies. It is clearly regarded by farmers as an essential means of using their natural-resource bases and is a key risk-aversion strategy, not merely a relic of the former pastoralist culture in these regions. Despite their environmental and demographic differences, all three investigated areas are characterized by generalized agropastoral production systems involving combined animal herding and cultivation. Rarely is a purely farming or a purely pastoralist production unit found in any of these regions. When it does occur, it is usually an indication either of extreme impoverishment or total incorporation in a market-oriented, modern economy.

However, agropastoral systems in these regions differ considerably in terms of herd composition. These differences depend on individual circumstances as well as, more generally, on population pressure and the availability of arable land versus rangeland. Possible combinations include cattle herds alone, mixed herds of cattle and sheep, and herds of sheep and goats. In the Chaouia, the most prevalent herd consists of cattle; in the Chichaoua, combined cattle and sheep herds are most common; and in Maroc oriental, sheep and goat herds are predominant. In all cases, livestock production, because of the comparatively high income-generating potential, is regarded as the key way means to maximize producer incomes. Thus, livestock production has a central strategic role within the overall production systems in all areas. This integration of livestock raising and cultivation is clearly a source of strength because it allows farmers to maximize their output years of adequate or abundant rainfall. However, because of population pressure and other changes, this integration of livestock production and cultivation is increasingly becoming dysfunctional in the case of multi-year droughts. This is because it relies heavily of the use of by-products from cultivation for animal feed and because, over time, available grazing areas have become reduced.

⇒ ***Agricultural production systems are characterized by diversification and flexibility*** in all three study areas. These two key principles allow farmers to cope with drought and achieve survival under extreme hazard conditions. *Diversification* is a key adaptive response and is found in the cultivation system, the livestock system, and in the mechanisms by which these two systems interact with each other. Flexibility is also apparent in both the cultivation and livestock systems. For example, the seasonality of cropping is not rigid. Farmers take advantage of random rainfall at different periods between November and May through planting either early crops (*bekri*), late crops (*mazouzi)*, or both. Flexibility as a principle is also visible in the livestock raising system, as farmers can chose between a relatively mobile, pastoral-nomadic-like pattern or a sedentary mixed-farming pattern, depending on rainfall conditions. In the Chaouia region, however, flexibility has been disappearing because of population pressure, relatively intensive land

use, limited fallow, and a trend towards simplification in the livestock production system wherein herds increasingly consist of cattle alone.

⇒ ***Fallow has a critical role within the agropastoral system.*** Fallow has an important, polyfunctional, essential role in both crop production and livestock rearing. It is universally recognized by farmers to be a major determinant in increasing crop output. During the fallow year, fields not only accumulate soil moisture from rainfall but also nitrogen, leading to increased yields when they are again put into crop production. In addition, fallow is also an essential part of livestock production in that stubble from the previous year's cultivation as well as weeds that grow on fields during the fallow year are vital for fodder. For these reasons, when fallow disappears from the agropastoral system due to demographic pressure, which reduces landholding sizes and farmer ability to leave land in fallow, farmers become more vulnerable to drought.

⇒ ***Farming output efficiency and vulnerability to drought are also related to other key factors.*** These factors include the following: (1) The actual time of plowing, which is related to the timing of the first fall rains in the October to November period. (2) The specific crops grown. Barley is the most drought resistant cereal crop—thus its domination in arid and semi-arid conditions. Hard and soft wheat are more sensitive to shortfalls of precipitation, and therefore are predominant only in the relatively humid Chaouia region. (3) The nature of the preceding landuse, whether fallow, plowed fallow, legumes, maize, or permanent cropping. Fallowing, particularly plowed fallow (*jachère travaillée*), helps to offset the negative effects of drought as it boosts crop output the following year. (4) The amount and type of labor inputs (e.g., animal traction versus modern machinery) allocated for the preparation of the soils. (5) The type of soil in relation with the amount of rainfall. Heavy soils are excellent agronomically when rainfall is above average rainfall. However, light soils have advantages during years of below average rainfall.

In general, many of the impacts of drought on society are related to the duration of drought. One year of drought following a normal rainfall year has far fewer negative impacts at the rural household level than is commonly assumed because of traditional drought-coping strategies, including stockpiling of grain and fodder during higher-than-normal rainfall years. The general calculation among the farmers surveyed is that "good years cover the bad years." That is, farmers base their production strategy on a two to three year time frame, rather than on a one year basis). Only when drought lasts more than a single year do its effects generally become critical at the household level. When drought lasts more than a single year, stockpiles of grain and fodder become exhausted, throwing household economies into crisis and threatening starvation for both livestock and people. Production maximizing strategies during "normal" or abundant rainfall years to mitigate drought impacts are decisive.

⇒ ***Traditional farmers employ a standard suite of drought-coping strategies*** to cope with severe drought conditions. These include the following: (1) Grain and

animal fodder are stockpiled. There are many different types of traditional storage systems, including *nader*-s, which are conical stacks of hay and straw, and *matmora*-s, which are underground grain storage pits. Stockpiling grain and fodder is an effective way to buffer the drought's impacts, particularly if it continues for more than a single year. (2) Herd size is highly flexible, depending on the severity of drought. Farmers try to maintain a small herd no matter how severe the drought. This minimum herd allows a new start once rainy conditions return. Insistence on retaining a minimum herd might appear to be non-economic or even irrational in many cases (e.g., during drought years, a day's worth of fodder for an animal may be roughly equal to a fourth of the value of the animal). However, the expectation of better conditions requires that this minimum herd size be available for a good start again. (3) There is flexibility in the definition of a family's basic nutritional needs. Reducing food consumption is a basic drought-coping strategy.

⇒ ***The increased use of modern farm machinery has, paradoxically, both increased and reduced the drought hazard.*** On the one hand, modern farm machinery has increased vulnerability to drought. This is because it has enabled farmers to cultivate marginal, low-rainfall, rangeland areas. While farmers can obtain crops on these marginal lands during higher-than-normal rainfall years, they are highly drought-prone areas. As the percentage of cultivated land in low-rainfall areas has increased, so has the drought hazard and the impact of drought on agriculture in Morocco. On the other hand, use of modern farm machinery has also become a drought-coping strategy as it has allowed for both rapid planting following the first rains as well as quick response to peculiar rainfall conditions. For example, in case of late spring rain when previously planted crops have failed, modern farm machinery allows for rapid replanting. Thus, mechanization dramatically increases farm output during favorable rainfall years through increasing the plowing power of the individual family compared to the traditional animal-based plowing. However, it also increases the negative impacts of drought when the drought extends over the entire year. Modern farm machinery has helped agricultural production in Morocco become a "high risks, high rewards"" game.

⇒ ***Farmers have adopted other general drought-coping strategies.*** These include the following: (1) Use of fertilizers to improve output; (2) intensive livestock raising of cattle in stables to increase income; (3) irrigation development wherever possible, through digging of new wells, use of motor-pumping, and use of diversion devices to concentrate runoff toward plots; (4) reliance on off-farm income to supplement farming resources; and (5) temporary human migration to urban areas.

In addition to these general responses and trends, field surveys also identified *drought-related patterns unique to each of the study regions*. These are identified for each region:

The Chaouia

The Chaouia's relatively humid environment, the longstanding character of its agricultural settlement, and its high population pressure make this region distinctive. Soft and hard wheat account for most of the cultivated area. Most land holding are relatively small (less than 5 hectares). Open grazing land has become severely reduced and is limited now to a few small areas such as valley of Mellah river. The largest livestock herder surveyed had only 50 sheep and 10 cattle. Goats and camels have completely disappeared from the region. To mitigate drought impacts during the two successive dry years 91-92 and 92-93, farmers reduced their herds, relied heavily on non-agricultural activities, dug wells, and migrated to Casablanca and other major urban areas (3 families permanently abandoned the countryside and 30 migrated temporarily). Attempts to plant late crops after early crops failed met with uneven results. After two successive years of drought, only 28 out of 192 production units still had any remaining reserves of grain.

Following the return of rain in the exceptionally wet year of 1993-94, modern livestock rearing based on stables and fodder instead of extensive, natural pastures-based grazing was the rule. After two successive years of drought, most production units had eliminated their herds; only a few managed to keep some livestock (10 sheep and 3 cattle was the largest remaining herd surveyed). Virtually no fallow land was observed except on larger holdings. Cultivation of *mazouzi* late crops (chick peas and maize) were reduced as early rains were good and most land was put into wheat cultivation. Farmers have seized the opportunity to offset the impact of the two previous drought years through maximizing grain production. Unfortunately, the virtual elimination of fallow has increased the vulnerability of the region to future drought. Farmers have resorted extensively to credit agencies or informal networks to cover the expense of putting their land back into cultivation (e.g., to purchase seeds and fertilizers). Use of modern farm machinery was universal; farmers without their own machinery contracted with more prosperous neighbors or specialized mechanized farm service providers. Cereal yields were exceptional, ranging from 30 and 60 quintals per hectare. Hay and straw were extensively stockpiled. Part of the harvest was sold to buy animals and/or to pay credits. All 30 temporary migrant families returned.

The Chichaoua and Maroc Oriental

The drought years of the early 1990s put both regions into a crisis status. In part, this is a result of the disappearance of grazing lands which permitted extensive stockraising in the past. In both of these regions, there has been a major shift into agropastoralism. The average area per production unit is around 20 hectares. Most land is officially collectively owned but, in fact, has become privatized. The Chichaoua had a good agricultural year in 1989-90. This was followed by three consecutive years of drought, with the 1992-93 agricultural year the worst drought year. The length of this drought created severe hardship. Almost all farm families became heavily indebted and had few remaining resources to respond when abundant rainfall returned during the agricultural year of 1993-94. In 1992-93, some planting of early crops was undertaken

but entirely failed. Seventy percent of the surveyed production units have at least one close relative in an urban area who helps the rest of the family remain on the land (16% had three relatives or more in urban areas lending assistance). Surprisingly, almost of fourth of the migrants to urban areas were female. The motto of this migration phenomenon was "*partir pour rester*" (leave to remain). Around seven percent of the migrants were working outside Morocco.

During the subsequent abundant rainfall year of 1993-94, early crops were planted. However, because farmers had already through dire necessity eaten their stockpiled grain and no local seed was available at the market, farmers had to rely on "commercial" seeds available in the market. The resistance of these seeds to drought is questionable, possibly increasing the vulnerability of these regions to future droughts. Due to limited resources, most peasants had to engage in associations or contracts in order to be able to function during this rainy year. Barley was the most widespread cultivated crop, accounting for at least two-thirds of the cultivated land in these regions. Near mountains, where better moisture conditions are found, wheat was more common. Barley and wheat yields varied from a low of around 4 quintals per hectare to a high of around 20 quintals per hectare with most production in the 10 to 12 quintals per hectare range. By-products of straw varied from 3 to 7 quintals per hectare.

In conclusion, field surveys in the three strategically chosen regions of Morocco validated the major underlying assumption of the research project—that a man-made, drought-prone agricultural system has emerged in Morocco. This drought-prone system has emerged as a result of societal changes and human activities. In all three study sites, increasing population pressure and higher market demand has exerted pressure on local natural resources, resulting in the extension of cultivation to lower-rainfall areas and the reduction of fallowing. Pastoral-nomadic units of production are gradually becoming sedentarized and/or marginalized. In all cases, landuse changes have entailed a dramatic increase in vulnerability to rainfall shortages. Data collected suggest that most Moroccan farmers can successfully endure only one year of meteorological drought without significant hardship. If drought continues into a successive year or years, socioeconomic impacts begin to become critical, even disastrous.

Increases in vulnerability to drought were generally observed in all three regions. It was also apparent that the severe droughts during the early 1990s hastened the transformation of society and the economy in the arid to semi-desertic sites investigated in Maroc oriental and the Chichaoua, where pure pastoral nomadic practices have disappeared, sedentarization of the population has become prevalent, and forms of agropastoral production now dominate. In all three regions, there has clearly been a dramatic vulnerability to rainfall variability. Drought has become "normal".

A series of adaptive strategies have developed to counteract this vulnerability. Major principles of adaptation involve increasing flexibility in the production system and diversification as a key risk-mitigation response to a rainfall variability. Production units engage in both cultivation and livestock raising; cultivation encompasses a diversified

variety of crops, including some new crops, as well as diversification into early and late planting; animal rearing involves a diverse variety of livestock most appropriate to the area, including cattle, sheep, and goats (even camels in the Chichaoua). Animal feed is of a great variety and can be obtained locally or through long-distance migration, farm-produced or purchased in the local market, commercially manufactured or natural (weeds, straw, etc.). Socially, there is flexibility in the allocation of familial labor resources, which allow for short-term migration of a few family members (usually males) in search of external resources (i.e., off-farm income). Reliance on off-farm income has gradually increased over time. Even during normal years, it is significant. During drought years, it becomes critical. In the severe three-year drought in the Chichaoua during the early 1990s, around 80 percent of the survival resources came from outside the farm. Technologically, mechanization has been a key response to drought. It has allowed farmers to plant immediately following the first rainfall to allow the optimal use of available water resources in soils. Mechanization has also allowed farmers to maximize the cultivated area during higher-than-normal rainfall years. Finally, it has given farmers a second chance to plant in case of early crop failure.

2.2 Regional and National-Level Research

2.2.1 Methods Employed in Regional and National-Level Research

At the regional and national levels, project researchers analyzed crop production statistics, meteorological data, and census data. These researchers also acquired and analyzed Landsat MSS imagery of the three study-site areas. This imagery was diachronic, covering both the mid-1970s and the early 1990s. "Windows" of the study sites were cut out of the larger MSS images. NOAA/AVHRR weather satellite images covering Morocco as a whole for the drought and abundant rainfall years of the early 1990s were also acquired and analyzed. Project researchers used these satellite images to evaluate the regional and national impacts of drought. These data sets were integrated into a GIS system for analysis as well as future management. Most importantly, at the national level, project researchers analyzed historical data and information about rural Morocco and drought's impacts.

2.2.2 Results from Regional and National-Level Research

Examination of the historical literature confirms that drought occurs frequently in Morocco. An exhaustive historical survey of drought in Morocco from the late 9th century to the early 1900s discovered that there were 49 major drought-related famines during this period (Bois 1957). Since 1912, when Morocco was divided into French and Spanish protectorates, this country has experienced around 28 years of agricultural drought. The average interval between droughts during the past eighty-five years is only about three years. Unfortunately, there is no detectable periodicity.

Drought has major socioeconomic significance in Morocco because rainfed cereal cultivation (primarily of wheat and barley) is predominant. Since pre-Roman times, this region has specialized in cereal crops, mainly wheat and barley. During

much of this period, and until the 1930s, Morocco was a major exporter of grain to Europe. Today, cereal crops still account for approximately 85 percent of the country's total cropland, and are primarily produced by rainfed or non-irrigated means. Wheat and barley are the mainstays of the national diet. Nutritional surveys reveal that cereals account for roughly 60 percent of the daily caloric intake and 65 percent of the protein supply. For the rural populations and urban poor, these percentages are even higher.

Drought in Morocco sharply reduces both cereal acreage and yields, causing total production to plummet. This poses an immediate food security threat. During a typical drought year, cereal imports rise dramatically, substantially increasing foreign debt. Food prices also rise, food shortages develop, malnutrition becomes more prevalent, herds perish or are slaughtered for lack of forage, peasants abandon their land and flock to the cities, and soil erosion and desertification increase.

Good rainfed cereal harvests in Morocco require adequate rainfall during both the planting season, normally from October to December, and subsequent growing season, which extends until harvesting sometime between April and June in Morocco and even later in eastern regions of Morocco. Poor harvests or crop failure related to drought can result from rainfall shortages during either season. Given the potential for extreme interannual variability in precipitation levels, 400mm annual average precipitation is normally considered the threshold for viable rainfed cereal production in Morocco (Lery 1982). However, the timing of rainfall is just as critical as the total. For example, if the entire precipitation in the Marrakech region during October and November falls during a single intense cloudburst, most will disappear as runoff and be unavailable for crop use. Thus, regardless of the total amount of rain, severe drought conditions will probably develop. By contrast, as little as 250mm of rainfall can produce good harvests if it occurs at critical moments during the agricultural year (Bowden 1979).

Project research at the regional and national levels enabled the research team to make the following **major generalizations** relevant to the "drought follows the plow" hypothesis:

⇒ ***Agricultural technology has a major role in determining vulnerability to drought.***

Probably at least a third of the total tonnage of cereals in Morocco is still produced exclusively by traditional means, including animal traction and the light-weight swing or scratch plow. This traditional technology is more environmentally sensitive than modern agricultural machinery, and helps prevent soil erosion. However, it has two critical and interrelated shortcomings:

First, plowing with the traditional plow is a very slow process. In all, a farmer and his draft animal must trudge approximately 60 kilometers to put a single hectare into production (Cleaver 1982). Commonly, fields must be traversed twice: once to break up the soil and a second time to plow under the broadcast seed. Second,

peasants can't normally begin plowing until approximately 150mm of rain have fallen, softening the earth. This is because, during the dry summer season, the ground becomes baked too hard for the light scratch plow to penetrate.

Having to wait for rain presents major problems. The window of opportunity for planting is relatively limited, given the short growing season before the arrival of hot, arid summer conditions. Planting must generally be finished by the end of December or early January. Thus, if the autumn rainy season is delayed or short-lived, the amount of cropland that can be put into production is reduced.

The resulting contraction in acreage can be quite substantial. For example, during the 1980s, annual acreage figures for cereal cultivation fluctuated by well over a million hectares in Morocco (Swearingen 1992). To place this in context, the fluctuation was the size of roughly a fourth of Morocco's average annual cereal acreage during this decade. This enormous fluctuation obviously has a direct correlation with fluctuations in precipitation. However, it is at least partly due to the technological limitations of the traditional plow vis-à-vis Morocco's physical environment.

Given the limitations of the traditional plow, the timing of rainfall is critical. Low production levels associated with drought can result not only from diminished crop yields, but also from a reduction in the acreage planted during the October-December period. Indeed, even when rainfall during the rest of the year is satisfactory, poor harvests can result if the autumn rains are late or poor.

Having to wait for rain before plowing <u>not only</u> reduces crop acreage: it also significantly lowers crop <u>yields</u>. The reason is that a large percentage of the total precipitation has already evaporated before the seeds even get in the ground with the traditional system. The magnitude of this factor is suggested by field tests in Morocco. These tests have demonstrated that planting (with tractor and steel plow) <u>before</u> the arrival of the rainy season can improve crop yields by roughly 30 percent—without any other changes in production methods (Cleaver 1982).

Moroccan peasants and government agronomists are well aware of the constraints of traditional technology. The government has used financial incentives to promote agricultural mechanization, particularly since the late 1970s (Swearingen 1987a, 1992). As a result, the tractor and modern plow have substantially replaced animal traction and the traditional plow, as the field research conducted through this project has clearly demonstrated. More prosperous landowners, benefiting from government subsidies, have almost universally mechanized their operations. Often, they gain extra profit from plowing the fields of neighbors who cannot afford to mechanize. In addition, plowing services are widely provided by an emergent group of rural entrepreneurs who have purchased farm machinery to plow other's fields. Smaller or poorer landowners who cannot afford to purchase tractors and modern plows usually find it cheaper to hire plowing services than hand labor. This, too, has contributed to the expansion of mechanization.

However, a sizable percentage of the landowners can afford neither agricultural machinery nor plowing services. Furthermore, many landholdings in Morocco are too small, fragmented, or remote for plowing services to be feasible. Or, they are located on slopes too steep for mechanized operations. Thus, animal traction and the traditional plow will continue to be extensively used. This will help to prevent soil erosion, but it will also help preserve the region's vulnerability to drought.

Ironically, the Moroccan government has promoted mechanization as a way to drought-proof their rainfed cereal production sectors (Swearingen 1987a, 1992). Expansion of mechanization has helped overcome the problem of reduced cereal acreage from sparse or late rains during the planting season. In this way, the drought hazard has been mitigated. However, as the field research confirmed, mechanization has initiated a reverse trend that is substantially increasing the drought hazard in Morocco. In this regard, mechanization is the latest in a series of historical trends that, overall, have progressively increased Morocco's vulnerability to drought.

⇒ ***Policies implemented during the colonial period (1912-56) contributed to Morocco's vulnerability to drought.***

Prior to the colonial period, agriculture in most of Morocco consisted of an extensive system of dryland cereal cultivation and animal husbandry (Swearingen 1987a). Most land was communally owned. Landholdings were usually dispersed to provide for equity and to help counter the risk of crop failure. Each peasant commonly farmed some 5 to 10 dispersed plots. Surplus grain from bountiful harvests was stockpiled to cover crop failures during drought years. Fallowing (periodically letting cropland lie idle instead of cultivating it) was widely practiced. Fallowing both replenished soil moisture and helped to restore soil fertility. Low population pressure gave the arable expanses of primary interest to the French colonists a relatively underutilized appearance.

French colonial planners viewed Morocco as a major exception within France's colonial realm. With its proximity to Europe, and the Mediterranean climate of its coastal plains and plateaus, this country along with its neighbors Algeria and Tunisia was perceived as fit for large-scale French colonization. In all 3 countries, colonization dislodged peasants from much of the best land. Europeans acquired roughly 30 percent of Algeria's arable land, or 2.7 million hectares; nearly 20 percent of Tunisia's land, or 800,000 hectares; and 13 percent of Morocco's land, or 1 million hectares, including most of its best land. Exacerbating the effect of European colonization was land concentration by native large landowners. During the colonial period, indigenous landowners allied with the French were able to amass sizable landholdings in all 3 countries. In Morocco, 7,500 Moroccan landowners acquired 1.6 million hectares, or 21 percent of the arable total (Swearingen 1987a, 1987b).

Land concentration during the colonial period had two important consequences: First, as land was expropriated, most peasants became concentrated on a diminished amount of land. Much usurpation was conducted by private European land speculators and settlers as well as by indigenous landowners. However, French colonial authorities exercised an official policy of *cantonnement* to create landholdings for state-sponsored colonization. They calculated how much of a given tribe's territory was needed to support the tribe, then 'cantoned' tribal members on that land and appropriated the rest for colonization. Their calculations rarely allowed for the growth of the tribal group.

One major effect of land expropriation was that it reduced peasants' ability to let part of their land lie fallow (Swearingen 1992, 1994, 1996). With reduced landholdings, many peasants had to put all of their land into cultivation to produce sufficient food for their household needs. Reduction of fallow significantly increased the potential for drought. The primary purpose of fallowing in semi-arid regions like Morocco is to allow soil moisture to accumulate (WMO 1975). Approximately 20 to 25 percent of the precipitation falling during the fallow period (roughly 18 months between harvest and planting) is retained in the soil. Thus, fallowing substantially boosts the available water supply for subsequent crop use. In low-rainfall areas, this soil moisture component is often the critical difference between a successful harvest and drought. With the reduction of fallowing, this buffer was lost, and vulnerability to drought increased. In addition, excessive landuse pressure caused soil fertility to decline. Declining yields, combined with reduced acreage, made it increasingly difficult for peasants to stockpile grain as a hedge against drought.

Second, large masses of peasants were dislodged to marginal land that was not sufficiently attractive for colonization. The marginal areas were commonly characterized by poor soils, unfavorable slope, and/or deficient rainfall. Previously, most of this land had been used only for livestock grazing. Because of its low-rainfall levels, it was more vulnerable to drought. Unfortunately, once cleared and plowed, it also became prone to soil erosion and desertification.

While land concentration was taking place during the colonial period, other significant changes were occurring. Health measures introduced by the French caused native death rates to plunge. Morocco's population expanded dramatically, with probably a sixfold increase during colonial times. This population explosion--combined with the expropriation of between a third and a half of the arable land by Europeans and indigenous large landowners--intensified pressure on remaining agricultural resources. Fallow was further reduced, peasant landholdings became increasingly fragmented, soil fertility continued to decline, and more marginal land was put under cultivation.

Already by the 1930s, squatter settlements or *bidonvilles* were developing around the major Moroccan cities, inhabited by peasants who could no longer be sustained on their land (Montagne 1952). The rural exodus became a human flood during drought years, when crop failures forced many peasants to sell or abandon

their land. During the catastrophic drought-related famine of 1945, for example, there was a wholesale reduction of small landholdings. The prevailing price for a hectare during this crisis period was a mere 50 kilograms of grain (Istiqlal 1954). This was only about a fifteenth of an average hectare's crop yield during a normal year.

Colonial agricultural policy, *per se*, also played a major role in deepening Morocco's vulnerability to drought. Between roughly 1915 and 1928, colonial authorities had a mandate from the *métropole* to substantially increase cereal production for France. The architects of this mandate were convinced that France's "Afrique du Nord" had been a bountiful breadbasket for Rome during classical times, and that France could restore this land to its former productivity (Swearingen 1985, 1987a). Various subsidies and bonuses were offered to encourage cereal cultivation, especially cultivation by mechanized means. High market prices were also offered, particularly for wheat. Agricultural mechanization and high crop prices enabled marginal areas to be profitably cultivated during higher-than-normal rainfall periods. Although Europeans and native large landowners were the primary beneficiaries of the subsidies and bonuses, lucrative crop prices also enticed peasant farmers into the cash economy and encouraged them to significantly expand their cereal acreage.

The colonial cereal policy produced the desired results. The area planted in cereals in Morocco grew from 1.9 million hectares in 1918 to nearly 3 million hectares in 1929 (Hoffherr 1932). This was an increase of roughly 60 percent. However, there were hidden adverse effects. Part of the new cereal acreage came from the reduction of fallow, increasing the potential for drought. Much of the rest came from the extension of cultivation to marginal low-rainfall areas. The proportion of cropland in drought-prone areas steadily increased.

Contributing to Morocco's vulnerability to drought was the fact that the colonial policy favored wheat production over barley. Previously, barley had been the predominant native cereal. However, wheat now became predominant, and consumer tastes changed to prefer this cereal. With the varieties at the time, the critical rainfall limits for barley were some 30 percent less than those for wheat. In addition, barley ripens and can be harvested significantly earlier than wheat; therefore, it is less vulnerable to the untimely onset of summer drought conditions (Dresch 1956). In short, by substituting wheat for barley, the colonial wheat policy increased the potential for drought.

⇒ ***Government reforms since independence have also contributed to increased vulnerability to drought.***

Following independence, Morocco gradually recovered ownership of colonial landholdings and engaged in limited land reform. However, much of the former colonial land passed into the hands of more prosperous native landowners.

Furthermore, most of the large landholdings acquired by native landowners during the colonial period were never subject to land reform.

For at least two decades following independence, the Moroccan government seriously neglected domestic food production. As a result, by the 1980s, Morocco was experiencing a severe food security crisis. The key symptoms of this crisis were declining *per capita* cereal production; alarming, ever-growing levels of cereal imports; heavy foreign indebtedness related to these imports, and massive food subsidy programs. By the early 1980s, Morocco was importing over a third of its cereal grains (FAO) and a large percentage of the population was experiencing hunger and malnutrition. The political implications of this crisis became clear by 1981, when Morocco experienced a bloody food-related riot. Similar food-related riots erupted in 1984.

Since the early-to-mid 1980s, Morocco has been engaged in major policy reforms with the overriding objective of increasing dryland cereal production. Reforms have included privatization of the state agricultural sector to improve efficiency and promotion of modern seed varieties and fertilizers. Of the reforms that have helped increase drought, however, the most significant involve changes in crop prices.

For many years following independence, the Moroccan government maintained tight control over producer prices of basic food crops. Prices for these crops, cereals in particular, were held artificially low until the 1980s. Indeed, for much of this period, crop prices were as low as a fourth to a half of what they would have been without government intervention (Cleaver 1982). The rationale was that low crop prices would enable the government to provide cheap food to its urban populations, helping to keep wages low, thereby assisting industrialization and other urban development initiatives. An ulterior motive behind the cheap food strategy was to help prevent social unrest among the growing ranks of the urban poor. Unfortunately, low crop prices acted as a major disincentive to farmers, creating a vicious spiral of declining production (Swearingen 1987b).

Beginning in the late-1970s, fixed producer prices for cereals and other basic food crops were gradually raised. By the mid-1980s, the government had increased producer prices of barley and wheat to approximately <u>twice</u> world market levels. The stimulus effect was remarkable. Assisted by good weather, Moroccan production of cereals grew from an annual average of 3.8 million tons during the 1980-1984 period to 6.6 million tons during both the 1985-1990 and 1988-1992 periods. In part, this growth has come from improved yields. In significant part, however, it has come from an expansion of cereal acreage. Average annual cereal acreage during the 1980-1984 period was slightly over 4.4 million hectares. However, by the 1988-1992 period, it had expanded to 5.4 million hectares--an increase of nearly a fourth (FAO).

This increase has resulted both from the reduction of fallow and the extension of cereal cultivation to marginal rangeland. Already by the early 1940s, cereal cultivation had reached the 4.4 million hectare figure that still prevailed during the early 1980s. In short, virtually all viable cropland was already in production a half century ago. However, encouraged by extremely high crop prices since the mid-1980s, Moroccan farmers have dramatically reduced the acreage left in fallow. Because continuously cropped areas are not allowed to accumulate soil moisture, as they do when fallowed, the reduction of fallowing has effectively deducted an input of water from the cropping system and substantially increased the vulnerability to drought. Besides reducing fallow since the mid-1980s, Moroccan farmers have also substantially expanded the area of cereal crops in marginal low-rainfall areas. These marginal new lands are not only prone to desertification and wind erosion; they are also highly vulnerable to drought.

Government efforts to promote mechanization have facilitated the expansion of cereal cultivation to drought-prone rangeland. The tractor and disc plow have converted large stretches of rangeland to cereal acreage. Some of these new lands normally receive as little as 200mm of annual rainfall (Dresch 1986). Their poor soils can sustain cultivation for a few years, as long as higher-than-normal rainfall prevails. However, the return of normal low rainfall levels ultimately forces their abandonment. Desertification quickly advances in the abandoned areas. In effect, farmers are destroying the grazing potential of these lands through clearing the natural vegetation, unsustainably "mining" their fragile soils, and leaving them exposed to wind and water erosion.

2.3 Conclusion

To summarize, project research—conducted at both the micro-scale and macro-scale—has demonstrated that the drought hazard in Morocco has gradually been increasing due to a series of processes. This hazard has been increasing primarily due to the following two processes: (1) expansion of cereal cultivation to drought-prone rangeland; and (2) reduction of fallow.

During the colonial period, these processes were fostered by large-scale land expropriation; by the dislodging of peasants to marginal lands; by a cereal policy offering high crop prices and other incentives; by agricultural mechanization, which facilitated the mining of marginal areas during periods of higher-than-normal rainfall; and by population pressure associated with rapid population growth. Other significant factors include the gradual loss of peasant ability to stockpile grain as insurance against drought, and the progressive substitution of wheat for drought-resistant barley.

Since independence, these intensification processes have continued. Population in Morocco has continued to increase at high growth rates (though these rates have gradually declined). High growth rates, combined with virtual neglect of cereal production for two decades after independence, precipitated a food security crisis by the early 1980s. To counter this crisis, the Moroccan government has been

following policies designed to boost the country's cereal production. Unfortunately, these policies are further promoting cultivation of drought-prone rangeland and reduction of fallow.

Within Morocco as a whole, a precariously high level of cereal land is now perennially vulnerable to drought. Indeed, at least 50 percent of the cereal acreage is now located in "low rainfall" areas, which the Moroccan considers to be areas receiving less than 400mm per year. In the government's survey of agricultural areas during the 1983-84 season, it found that 51 percent of the country's cereal crops were being grown in low-rainfall areas (AID 1986). Since then, the percentage of drought-prone land has continued to increase.

Although government policies to mitigate drought have provided dramatic increases in cereal production, they have not been economically sustainable. In addition, they have helped to gradually erode away traditional buffers protecting Moroccan society from drought. This society has been resourceful and resilient. At the household level, farmers have developed a suite of drought-coping strategies based on the principles of flexibility and diversification. However, research at both the field and national levels clearly revealed that Morocco is becoming increasingly vulnerable to drought. The general validity of the "drought follows the plow" hypothesis was confirmed: growing population pressure, the scarcity of viable new cropland, environmental degradation, and other key factors are forcing Morocco to expand agricultural production to marginal low-rainfall areas, creating increased vulnerability to drought.

3.0 IMPACT, RELEVANCE, AND TECHNOLOGY TRANSFER

This PSTC-funded project had the following significant impacts:

(1) The project helped the Université Mohammed V in Rabat develop the technical capability to monitor and assess drought and other critical environmental problems. Specifically, the Université Mohammed V was strengthened through two primary mechanisms: *First*, key personnel were trained in the use and application of GIS techniques for environmental analysis. These personnel, in turn, have trained and will likely continue to train other faculty members, technicians, and graduate students. *Second*, the project equipped the Rural Geography Laboratory at the Université Mohammed V with state-of-the-art GIS equipment. This university now has a fully operational GIS research and training facility. Its expanded capability should allow it to successfully undertake analysis of critical environmental problems in Morocco.

(2) On a policy level, we expect the project results to influence Moroccan government policy. This was the first detailed study of drought in Morocco that examined drought's socioeconomic impacts on local, regional, and national levels. Results of the project have been disseminated to high-level Moroccan policymakers and should help inform policy future decisions related to drought and mitigation of its effects.

(3) On a theoretical level, the project results should contribute to emerging theory on the human dimensions of global environmental change. Specifically, we expect these project results (which have appeared and continue to appear in high-profile publications) to increase awareness of the relativity of drought as a natural hazard, of how this phenomenon is shaped by the societal context in which it occurs, and of how developing countries are becoming more vulnerable to this hazard.

4.0 PROJECT ACTIVITIES/OUTPUTS

4.1 Meetings Attended

Dr. Will Swearingen presented a project-related paper titled "Testing the drought follows the plow hypothesis in Morocco" at an international workshop titled "ADRAW: The African Drought Research Agenda Workshop" in Nairobi, Kenya, 2-4 June 1993. This conference was funded by the African Academy of Sciences, the U.S. National Science Foundation, and the American Meteorological Society.

Dr. Will Swearingen presented a project-related paper titled "Climate impacts on development: drought and policy changes in Morocco" at an international conference titled "Creeping Environmental Phenomena" at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, 7-9 February 1994. This conference was funded by the United Nations Environmental Programme.

Dr. Abdellatif Bencherifa presented a project-related paper titled "Vulnerability to drought and environmental degradation: empirical observations in semiarid and arid areas of Morocco" at an international UNDP-funded conference on "Creeping Environmental Phenomena" at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, 7-9 February 1994.

4.2 Training

GIS and remote sensing training at Montana State University's Geographic Information and Analysis Center (GIAC) provided for key Moroccan scientists. Trainees: Dr. Abdellatif Bencherifa (July 15 to August 30, 1993) and Mr. Fathallah Bennani (July 15 to October 14, 1993).

4.3 Publications

Swearingen, W., 1992, "Drought hazard in Morocco." *Geographical Review* 82:401-12.

Swearingen, W., 1994, "Northwest Africa." In M.H. Glantz, ed., *Drought follows the plow*. Cambridge, England: Cambridge University Press, 117-133.

Swearingen, W., 1996, "Is drought increasing in Northwest Africa? A historical analysis." In W. Swearingen and A. Bencherifa, eds., *The North African environment at risk*. Boulder, CO: Westview Press, 17-34.

Swearingen, W. and A. Bencherifa, Forthcoming, "An assessment of the drought hazard in Morocco." In D. Wilhite, ed., *Drought* volume in *Hazards and Disasters: A Series of Definitive Major Works.* London: Routledge.

Swearingen, W. and A. Bencherifa, Forthcoming, "Drought in Northwest Africa." In M. Glantz, ed., *Handbook of Weather, Climate and Water.* New York: McGraw-Hill.

5.0 PROJECT PRODUCTIVITY

The project accomplished most—although not all—of its goals. It fully accomplished its overriding purpose, which was to determine to what degree Morocco, a representative drought-prone developing country, has become more vulnerable to drought owing to human activities. Additionally, it fully accomplished its objective of rigorously testing the "drought follows the plow" hypothesis. Through evaluation of key variables (including the patterns of agricultural intensification and the demographic, political, economic, governmental, technological, and environmental factors behind this intensification), the drought hypothesis was confirmed although significantly refined. Project results represent a significant contribution to the emerging frontier of theory on the human dimensions of global environmental change. The field research component of the project ultimately became much more important than originally planned. In fact, the extensive six-part interviews of 335 rural households in three strategic regions of Morocco over a twenty-month period represents one of the largest and most detailed field research projects on drought ever undertaken in the developing world.

Unfortunately, the project fell partly short of achieving its second major objective: to develop an efficient, cost-effective methodology for LDCs to use to assess and monitor their drought hazard. The principal reason is that this objective proved to be overly ambitious and unrealistic. During the course of the project, the research team came to fully appreciate the complexity and relativity of drought, which has meteorological, hydrologic, agricultural, and socioeconomic dimensions as well as both physical and human-induced causes. The project team ultimately recognized that its primary focus, the socioeconomic dimensions of drought, vary from region to region even in Morocco. As a result, assessing and monitoring drought is relatively context specific and not amenable to the development of standardized methodologies.

6.0 FUTURE WORK

The research funded by PSTC is continuing. The principal collaborators, Dr. Will Swearingen and Dr. Abdellatif Bencherifa are continuing to analyze and synthesize the data gathered through this project and publish the resulting findings. In addition, at least two of the other Moroccan scientists involved with the project are continuing to investigate major questions raised by the project .

7.0 LITERATURE CITED

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