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# Energy and Agriculture in Morocco: Linkages in the Food System

Final Report

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# I. INTRODUCTION -

## Scope of Problem

One of the biggest challenges today is the necessity to feed the burgeoning world population. This will require future increases in food production if only to maintain the present less-than-adequate nutritional levels. As population increases, arable land per capita decreases. Additional energy will be needed not only in production agriculture to augment crop yields but in the entire food system from farm gate to food plate.

Energy is clearly a fundamental requirement of food production and takes many forms. It is embodied in sunlight for photosynthesis, the soil in fungi and bacterial populations, mechanical and human labor. The fact that fossil energy has helped mankind manipulate ecosystems thus contributing to higher living standards is well-documented. (Stout; Pimental; Leach; Fluck and Baird; etc.)

The substitution of fossil fuels for organic and animate energy in the West and the explosion of Green Revolution technologies contributed directly to raising the productivity of land and labor. This enabled a dwindling agrarian population to feed a growing urban one. These changes were predicated on the use of cheap fossil fuels.

Energy can be difficult or expensive to supply as many countries struggle with fuel import deficits while concurrently facing the vagaries of world market price fluctuations for their exports, often agricultural commodities. Even though world oil prices have regressed in recent years, many developing countries pay higher real prices for petroleum, as their currencies weaken in relationship to the U.S. dollar. (For example, between January and June 1983, when international oil prices around the world were dropping and OPEC's solidarity on price floors weakening, domestic prices for petroleum actually rose 14 percent in Morocco due to the dirham devaluation against the dollar, in which oil prices are denominated. AID CDSS for Morocco, FY 1986)

Some authors caution that modernization of the agricultural sector in developing countries is now threatened by the high cost of imported oil products to support irrigation projects, fertilizers, and farm machinery. There is evidence that food production has been severely curtailed due to the lack of energy-related farm inputs. For example, India alone is widely reported to have lost 10 million tons of grain through the lack of fertilizers (from Leach, Energy and Food Production, cited in Mohr).

The majority of agricultural producers in the developing world rely on human and animal energy and low productivity technology. The increased scarcity and rapid price increases of purchased energy inputs limits the conversion of many farmers to their use. At the same time, the rural population is depleting traditional sources of energy, primarily fuelwood and agricultural wastes, due to land clearing for cultivation and for cooking fuels. These combined conditions are thwarting the Third World's objectives of increasing food production for indigenous population as well as for exports and foreign exchange.

Furthermore, an insistent and explosive fact confronting most developing nations is the rapid exodus of population from rural to urban settings. If basic energy requirements of all kinds for -- cooking, lighting, village industry, food processing, and transport -- are not met at a level that provides farmers and their families with the security, self-respect, and amenities that make rural life at least not worse off than life in the cities, they will leave the land if they can. While these energy issues may not relate directly to food production, they nonetheless have a bearing on farming. The firewood crisis is one example. Possible solutions such as afforestation, fuel crops, and converting residues to fuels have deep implications for agriculture. (Leach, "Agricultural Production: Research and Development for the 1980's.")

Potential Solutions

Potential solutions may lie both within "agriculture as a consumer of energy" and "agriculture as a producer of energy" dimensions. As a consumer of energy, solutions include the designation of more petroleum to the agricultural sector. As pointed out in the Mitre study (Leigh, J.G. Energy and Development: Extended Analysis and Implications), increasing energy inputs to that sector appear to produce major changes in productivity, exceeding the beneficial impacts of increasing energy inputs to industry and transportation by a factor of ten in many countries.

It can be argued that even poor countries can afford to purchase petroleum for food production in the foreseeable future. Revelle reasons that if the need for additional energy for draft power, water power, and chemical fertilizer manufacture in India were to be met by petroleum products, 43 million metric tons would be needed. If all this petroleum could be imported, the cost would be defrayed by the export of about one-tenth of the increased food production.

In order to increase energy use in the agricultural system, many complex issues need to be addressed such as energy and food pricing, national import/export policy, i.e., promotion of food crops versus high-value export crops, etc. Some specific questions which LDC governments, policy makers, and development planners need to examine further are listed below. It should be pointed out that there may be no generic answers to these questions and that further analysis in a specific country context is required.

1. Should government budgets give priority to energy for agriculture? What interventions are most productive? Irrigation projects? Fertilizer production or imports? Mechanization programs or better use of animal and human energy systems?

2. How should fuels for agriculture be priced? Should they be subsidized? Are farm prices set too low to encourage higher-cost inputs?

3. Can alternative sources be used economically in the agricultural sector? If so, what, where and how much? How should these be encouraged? Can agricultural wastes or products (e.g. oils) be used as fuels? What is the potential for agriculture as an energy producer? What are the food vs. fuel issues in a specific country context?

4. Can/should agricultural production in export crops be used as a oreign exchange earner to offset oil import costs at the possible expense of food self-sufficiency?

5. How can it be ensured that energy is available for moving farm products to market, food preservation and processing? What infrastructure investments are necessary?

6. What energy inputs can be used to increase the productivity of subsistence farms?

The last question pertaining to the subsistence farmer hinges on the challenge of achieving growth with equity. Resource supply and distribution issues inevitably become enmeshed in socio-economic considerations. For example, in several developing countries a highly dualistic agricultural system exists with a small number of producers commanding a major portion of resources, including energy. Energy consumption is highly correlated to land size. Large farmers use their land as collateral to obtain energy-related inputs such as improved seeds and fertilizers. Mohr states perhaps the greatest single barrier to distribution of energy to the small-scale farmer is the unequal distribution of land ownership that prevails.

Question #3 concerns the "agriculture as a producer of energy" dimension in its discussion of whether agricultural wastes or products can be used as energy resources. Agriculture has the potential to become an energy producer not only for itself, but for other sectors. In a sense, this has occurred already with the provision of fuelwood and crop residues for cooking and lighting purposes. Agricultural waste products such as coffee husks, rice hulls, etc. are being recycled for use in running boilers, briquetted into charcoal for cooking fuel, etc. in some countries. The bio-energy connection is a fascinating and promising hope as a potential solution for providing energy necessary for agricultural production.

More efficient use of energy in agriculture and agro-related industries as well as improved farming practices can also serve to increase productivity in the food sector.

While a correlation is well established between increased fossil fuel inputs and increased agricultural productivity, an essential issue is how to overcome investment barriers farmers face that obstruct their adoption of these new technologies. This involves major issues concerning farm prices, i.e., are they set too low to encourage higher-cost inputs? How should fuels for agriculture be priced and/or should they be subsidized?

Better planning in projects is also crucial in relating energy use in agricultural projects to the national energy situation. For example, most projects are designed with the intention of their replication on a regional or national basis. Questions concerning the availability of the right fuel source, infrastructure for its distribution, and impact on balance of payments need to be examined.

Recurrent cost expenditures such as payment of energy-related inputs by project beneficiaries need to be examined in projects. Later in this report, an AID project is examined as an example. That particular project did not examine how beneficiaries would be able to pay for energy inputs. It was simply assumed that higher yields and consequently revenues due to the installation of an irrigation system would automatically cover these additional expenditures.

A brief set of questions which affect AID agricultural and energy project planners are listed below, several of which are later elaborated upon in the text:

1. Current agricultural projects: what are their energy impacts? Was energy considered in project design? How does project strategy affect/reflect the national energy situation?

2. Are there links between energy and agriculture in the Mission, in project analysis, management, and personnel?

3. Research/Information Needs: What is/isn't known about energy/agriculture? What data are most important for addressing policy issues? How can they be obtained most cost-effectively?

4. What future policy directions should the Agency take in these areas?

Questions #3 and 4 relate to the fact that the concern for the energy dimension is relatively new in most sectors, and particularly in the agricultural one. There are vast stores of knowledge compiled for soils, water, and biological resources. However, for energy, there is little information on its use in agriculture particularly in developing countries. It is usually considered to be of low priority because of its relatively small place in national energy budgets compared with other sectors. In fact, it is much higher when the entire food system is examined. LDC officials and development planners need to be better informed regarding energy and agriculture linkages in their pursuit of solving food-related problems.

Objectives of the Analysis

This report will address the energy implications of agriculture in certain designated countries beginning with Morocco. AID Country Development Strategy Statements (CDSSs), Agricultural Sector Strategy Papers, project papers and

evaluations (pertaining to energy and agriculture), as well as country data are reviewed to determine specific energy needs involved in Moroccan agriculture. Whether current AID projects are addressing these needs, whether alternative energy sources have been considered or whether more cost-effective energy supply options could be substituted are this writer's underlying concern.

An attempt is made to address the issues that may have important ramfications at many levels--including policy, program and project to increase energy use or improve the efficiency of its utilization in agriculture. While this report may raise more questions than it is able to answer, its purpose is to illustrate the cross-cutting edges between these two sectors in the overall goal of increasing agricultural productivity.

Both macro and micro descriptions concerning energy use in agriculture are discussed, i.e., the specific energy scenario in Morocco pertaining to agriculture are reviewed and then attention is given to relating energy use patterns by farm size. AID projects in Morocco are then examined to determine whether they are addressing energy needs in agriculture delineated by inputs (machinery, fertilizer, etc.) and components in the food system (production, transportation, etc.).

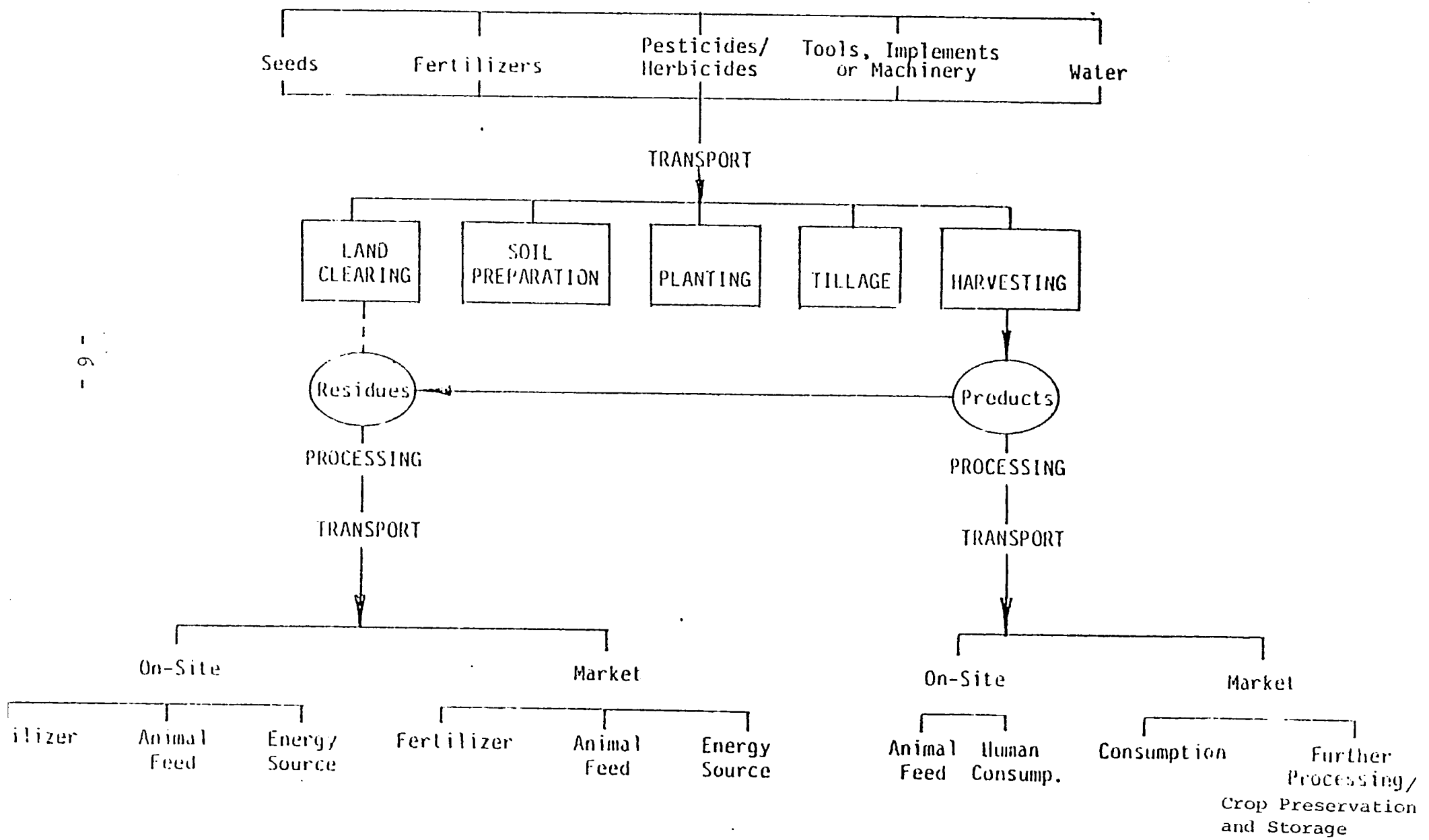
A methodological framework recently designed by Development Sciences, Inc. (DSI) for the Africa Bureau has been adapted in this monograph to address energy use in Moroccan agriculture. Both direct and indirect forms of energy are examined and defined as follows: 1) Energy needed for agricultural productivity can be considered as either the direct energy required to accomplish the planting or any other production operation with humans, animals, or machinery; and 2) the indirect energy required to manufacture chemicals or metal implements for farm use.

DSI discuss five major inputs of agricultural production - 1) tools, implements, or machinery, 2) fertilizers, 3) pesticides, 4) water and 5) seeds. These inputs can require direct energy in their use or application and also require indirect energy for their production and manufacture. Either of these, the direct as well as indirect, can be large. For example, fertilizers have a high indirect energy based upon their feedstocks, and production; and water, depending on its source, may require more direct energy in its actual distribution and use.

All these inputs require direct energy using human/animal labor, fuels or electricity to operate machinery for their application in farm activities such as 1) farm operations for land clearing, soil preparation, planting, tillage, and harvesting; 2) transportation which is needed to move all the inputs to the site as well as remove products and residues from the site as appropriate; and 3) agricultural processing and crop preservation and storage which may include only drying or involve further packaging or conversion steps to permit final consumption or utilization. Preparation for the home consumption of food is another activity that may require much more energy as was required to produce it. The patterns of energy usage in the agricultural system are illustrated in Figure 1.

Figure 1

THE ENERGY/AGRICULTURE INTERFACE



A complete energy balance for any farm system would include data on every input and on every energy-using operation. In reality, due to data limitations in LDC's and for the purpose of this analysis, it is not necessary to complete every energy transfer but rather to identify them in order to select those most relevant to the issue of energy use and productivity. Here the discussion is primarily restricted to energy used in agricultural production. Several Moroccan farm size categories are then examined to determine patterns of energy use.

## II. MOROCCO

### Background on Moroccan Agriculture

Morocco's population is estimated at 20.9 million (mid-1981), with an annual growth rate projected at 3.5 percent (1980 - 2000). About 60 percent of the population live in rural areas and agriculture provides about 52 percent of total employment. Per capita GNP was U.S. $860 in 1981, but about 45 percent of Moroccan families live at or below the estimated rural absolute poverty level of U.S. $238 per capita. Agriculture contributed 14 percent to Morocco's GDP in 1981. Cereals and pulses contributed 36 percent, livestock 33 percent, citrus 11 percent, vegetables 11 percent, industrial crops and forestry about 6 percent to the agricultural GDP in 1978-80. (World Bank: Small and Medium Scale Irrigation Report, World Development Report)

Of the total land area of the country, not counting the newly claimed portion of the Western Sahara, only about 18 percent is estimated to be arable; about 17 percent is pastureland, 17 percent is forest and scrub land, and the large balance is nonarable desert, mountain, or urban areas. (American University: p. 171) The majority of land is in cereals - wheat, barley, and corn. Most cereal farms produce in a traditional way for their own consumption. Despite the fact that cereals and pulses occupy about 70 percent of the cultivated area, a succession of poor harvests due to unfavorable weather and inadequate cultural practices have made Morocco a net importer of cereals. Imports totaled approximately two million metric tons in 1982, double the amount imported only six years earlier.(AID CDSS for Morocco, FY 1986)

The agricultural sector in Morocco includes both the traditional sector (5,710,000 ha; from Figure 2 ) which accounts for about 78 percent of the total potentially arable land area of the country, and the commercial/modern sector (1,590,000 ha; from Figure 2 ) which accounts for the remaining 22 percent of the potentially arable land.

Much of the land cultivated by traditional methods is devoted to grazing and yields per hectare of cropped land are less than those where modern methods prevailed. (See chart, Figure 3, for the yield figures for four crops produced by traditional and modern sectors). Traditional subsistence agriculture accounts for the bulk of the farm population.

Figure 2

Estimates of Land Ownership in the Modern and Traditional Sectors of Morocco

| How Owned | Modern Sector 1000 Ha | % | Traditional Sector 1000 Ha | % | Total 1000 Ha | % |
|---|---|---|---|---|---|---|
| Arable Lands | | | | | | |
| Private | 1,090 | 68.5 | 4,950 | 86.7 | 6,040 | 82.7 |
| State | 400 | 25.2 | 400 | 7.0 | 800 | 11.0 |
| Collectively | 10 | 0.6 | 350 | 6.1 | 360 | 4.9 |
| Charitable | 90 | 5.7 | 10 | 0.2 | 100 | 1.1 |
| Total Arable | 1,590 | 100.0 | 5,710 | 100.0 | 7,300 | 100.0 |

FOOTNOTES

Private land ownership dominates the land holding patterns in Morocco. In the modern or better land area, as shown in Table , 68.5 percent of the arable land is privately owned, 25.2 percent stated owned, and 5.7 percent charitable lands. Only 0.6 percent is collectively owned. The modern sector includes most of the fruit, vegetables, industrial and oil crops plus some of the wheat prodution.

In the traditional sector, 86.7 percent of the land is privately owned, 7.0 percent stated owned, 6.1 collectively owned and 0.2 percent are charitable lands. Cereals are primarily grown on this land.(12:132)

Source: Applied Agronomic Research Program for Dryland Farming in 200-400mm Rainfed Zone of Morocco, Campbell, R.R. et al, Mid-American International Agricultural Conservation Dryland Farming Team, 1977.

Figure 3

Estimates of Average Production, Area and Yields of Four Major Cereals: Modern and Traditional Farms

| | Production 1/ (000 MT) | (%) | Area (000 ha) | (%) | Yields (MT/ha) |
|---|---|---|---|---|---|
| Durum Wheat | | | | | |
| modern | 350 | (25) | 190 | (15) | 1.30 |
| traditional | 1,000 | (75) | 1,079 | (85) | 0.35 |
| total | 1,350 | (100) | 1,269 | (100) | |
| Bread Wheat | | | | | |
| modern | 231 | (55) | 178 | (40) | 1.30 |
| traditional | 189 | (45) | 267 | (60) | 0.70 |
| total | 420 | (100) | 445 | (100) | |
| Barley | | | | | |
| modern | 100 | (5) | 64 | (3) | 1.4 |
| traditional | 1,900 | (95) | 2,086 | (97) | 0.9 |
| total | 2,000 | (100) | 2,150 | (100) | |
| Corn | | | | | |
| modern | 100 | (30) | 21 | (5) | 3.5 |
| traditional | 250 | (70) | 391 | (95) | 0.6 |
| total | 350 | (100) | 412 | (100) | |

1/ Production is 1975-80 average. Estimate of area and yields from A. Ackles and J. Pederson, Grain Storage, Handling and Distribution in Morocco, Kansas State University, 1969 modified by USAID/Rabat. Yields multiplied by area do not correspond exactly to average production.

Source: Applied Agronomic Research Program for Dryland Farming in 200-400mm Rainfed Zone of Morocco, Campbell, R.R. et al, Mid-American International Agricultural Conservation Dryland Farming Team, 1977.

Modern agriculture was introduced by Europeans in the first half of the twentieth century and adopted by many Moroccan farmers. Although modern farming practices are used on a relatively small portion of the land, that portion includes some of the most fertile soil in the country and contributes to about 25 percent of all crops by value and over 85 percent of the export crops.(American University: p. 172) These farms are modern with respect to using commercial inputs of seeds, chemicals, and machinery and in many cases have access to lower cost on-grid electricity for irrigation pumping.

Perhaps predominant among the difficulties facing agriculture in Morocco is the lack of water and the year-to-year unpredictability of rainfall. The government has made great strides in the area of irrigation, (in the past, the GOM allocated over 70 percent of the funds allocated to the agriculture investment budget to the irrigated sub-sector), although some fear this occurred at the detriment of the dryland farming areas. The Government of Morocco (GOM) has taken a more balanced rainfall and irrigation approach in the 1981-1985 Plan and has shifted resource allocations from the irrigated sub-sector to a focus on small and medium-sized farms in the rainfed areas. (AID: Dryland Agriculture Applied Research Project)

Over 10 percent of the arable land accounts for the irrigation sub-sector. A full third of the smallest farms in the country has some form of irrigation. High value crops such as fruits, vegetables, cotton plus durum wheat and some forages are grown on the irrigated lands. (For further social and economic implications of the irrigated vs. dryland split refer to the section on AID projects. The most recent Morocco CDSS re-examines AID and the GOM's commitment to dryland agriculture due in part to pressures brought to bear by a three year drought).

## Moroccan Energy Consumption

Morocco consumes more energy than it produces, and the deficit continues to grow. By 1983, the country was importing about 85 percent of its commercial energy needs, most of which were in the form of crude oil. The balance of commercial energy production was derived from domestic coal, gas, and hydroelectricity. (The American University, Morocco: A Country Study)

As a result of dimished reservoir capacity due to the drought, hydroelectric facilities are currently generating only 3 percent of Morocco's power, where under normal circumstances they would provide about 15 percent. The difference must be made up by increasing imported oil. (AID, Morocco CDSS, FY 1986.) At the same time, it is estimated that wood, the principal energy source for a substantial portion of Morocco's population, is being harvested at 3 times the rate of replacement (World Bank, Morocco: Issues and Options in the Energy Sector).

Estimates of total energy consumption in Moroccan agriculture, excluding animate and indirect energy, range from about 200,000 TEP to 400,000 TEP (Tons of Petroleum Equivalent). (Aforementioned World Bank and $E^3I$ reports). The

most recent data compiled indicate that the figure is between 320,000 and 350,000 TEP, or about 4-5 percent of the nation's total energy consumption (McWilliams). It should be noted, however, that when fertilizer usage is included (especially for nitrogen), the energy used in agriculture increases significantly. (See Figure 7 for a detailed presentation of energy use in Moroccan agriculture).

## III. ENERGY USE ON MOROCCAN FARMS

An effort was made to examine the key characteristics of farms in an attempt to determine the level of energy inputs. Some detailed data giving information on human, animal, and machinery use for nine farm categories was obtained from a farm survey for the Haute Chaouia region of Morocco located in a dryland arable region (Morton). This study is part of a 51 Farm Study survey effort described in the Dryland Applied Research Project Paper. Crops examined included wheat, barley and legumes. One of the major finds of the survey is the degree to which mechanization has reached the smallest farms in Morocco.

The farm typology reflects a broad range of farm types. The range is from "micro" and subsistence where the majority of income comes from off-farm employment, to very large commercial farms where all production is marketed. In the middle are 3 types of medium-scale farms which both guarantee subsistence and allow some surplus production for sale. Unfortunately no correlation can be made between increased energy use and greater agricultural productivity in this instance because yield figures were not considered reliable and consequently not given. In general, yield differences between traditional and modern farming are large especially in the case of maize (see Figure 3 ). A description of these categories follow and are summarized in Figure 4.

### Categories I-IV:

The first four categories all own less land than required for family subsistence and sharecrop additional land. Even with sharecropping, subsistence is not guaranteed, and off-farm employment is a key part of the subsistence strategy. These farms have few draft animals and rudimentary traditional traction equipment. Their herds are very small and are made up of mainly shared animals. They use little formal credit, and few improved inputs. Even though they have too much family labor available for the area farmed, they may hire in additional labor or machinery at peak seasons.

### Categories V-VII:

Medium-scale farms (Categories V and VI) have 13-25 hectares of owned land, but may take additional land for sharecropping, and rent some land for grazing, while taking some shared animals in exchange for part of the annual increase of the herd. These farmers have sufficient draft animals to farm their land effectively, and additional animal-drawn implements.

FIGURE 4

MOROCCAN FARM TYPOLOGY (DRYLAND AGRICULTURE)

KEY FARM CHARACTERISTICS

| FARM CATEGORY | Average Area Cultivated Land (ha) | Area (Adult Family Worker) | Average Number of Draft Animals | Mechanical Equipment present/absent owned/rented |
|---|---|---|---|---|
| I | 3.03 | 1.24 | 1 | present/rented |
| II | 7.00 | 1.69 | 1.75 | present/rented |
| III | 7.60 | 1.76 | 2.0 | present/rented |
| IV | 12.35 | 3.20 | 4.0 | present/rented |
| V | 15.51 | 3.61 | 2.0 | present/rented |
| VI | 25.51 | 3.93 | 3.0 | present/rented |
| VII | 37.47 | 9.65 | U.K. | present/owned |
| VIII | 153 | N.A. | N.A. | present/owned |
| IX | - | N.A. | N.A. | present/owned |

Source: Adapted from Haute Chouia region of Morocco "A Beneficiary Profile of Haute Chaouia (Morocco), Alice L. Morton prepared for Agency for International Development, 1982.

U.K. : Unknown
N.A. : Not Applicable

AID/ST/EY:JFinnell:kh:1/30:2808N

Larger farms (Category VII), of about 40 hectares, may be divided into those that derive from inherited land, on which techniques used are more traditional, where more capital is invested in improved livestock and whose owners are older, and new farms which are based on rapid land accumulation, are owned by younger, urban-based entrepreneurs, and have higher levels of mechanization.

The older farms are essentially bigger versions of the medium-scale farms, relying largely on draft animals for at least some production operations, taking some land for sharecropping, and using a greater variety of aminal-drawn implements. However, they are more likely to have much of their land partially mechanized than are the medium and small-scale farmers, renting equipment for custom use.

Newer large farms tend to own their own motorized equipment, which they use on the farm and also rent out to others. They use almost no family labor, relying on hired occasional and permanent workers. These farms are well-off and modernizing. Livestock management is semi-extensive; cattle are stall-fed and improved breeds are taking over from local breeds.

Category VIII:

There is an additional category of modern farms which are on average four times as large as the well-off modernizing ones. Here, virtually all production is mechanized, using owned equipment. There is more motorized equipment and a greater variety of accompanying production implements. No family labor is used on these farms, and there tends to be one permanent employee who supervises all agricultural operations. It is these farmers who have the most access to improved inputs, and who use them most. All production is marketed. As stated earlier, the modern sector contributes to over 85 percent of the export crops.

Category IX is made up of absentee farmers who primarily rent land to other farmers.

Mechanization:

One of the major findings of the Haute Chaouia survey is the degree to which mechanization has reached the smallest farms in the region (in the Settat Province). Although motorized equipment is owned almost exclusively by farmers with more than 30 hectares, the small farmer has turned more and more to mechanization, renting equipment from private entrepreneurs, including the largest local farmers. Small farmers may work off the farm in order to earn wages to rent equipment to mechanize their own operation! The increased use of mechanization by the smaller farmers has been attributed to the high cost of labor during peak periods (up to 2.5 times the minimum industrial wage) and the saving of critical time for land preparation under semi-arid conditions when it is important to plant as soon as possible after the first rains.

Rates of mechanization vary across Haute Chaouia, being higher in the north than in the south and vary across farm types, with large farms clearly using more mechanization. (See Figure 5 regarding levels of animal traction use vs. tractor use).

Tractors/ Harvest Combines:

The level of mechanization appears to be somewhat higher than for other dryland areas of the country. For example, between 1969 and 1978, the number of tractors in the province increased from 896 to 2082, an increase of 132 percent as against 112 percent for the same period for the country as a whole. In 1978, this province, which comprises 7.23 percent of the arable land in the country, had about 10 percent of all tractors in Morocco and about 25 percent of all combine harvesters. As shown in Figure 6, tractorization has kept marginally ahead of purchase of combines, at least in some zones of the region.

A recent estimate based for the agricultural year 1981-82 is that 70 percent of all production operations - land preparation and planting and harvesting were mechanized in Haute Chaouia (although the land planted was less than in previous years due to shortages of seed from the drought). What impact this rate of mechanization has had on diesel fuel availability or whether fuel costs was a problem for the farmers was not elaborated upon. This increase in mechanization in only nine years is amazing.

Labor time estimates are given for the production of four main cereal crops by work days under different conditions of mechanization as follows:

| Crop Type | Non-Mechanized | Mechanized Planting | All Mechanized |
|---|---|---|---|
| Barley | 35-40 days/ha | 30 days/ha | 5 days/ha |
| Durum and Bread Wheat | 50 days/ha | 30-35 days/ha | 5 days/ha |

These data show that mechanization of harvesting saves more labor than does mechanization of land preparation and seedings. Since the machines for harvesting are combines, they are saving labor not just for cutting the grain, but also for gathering it and threshing it, operations which are done separately and paid for separately in the absence of combines. Mechanization of both processes may save as much as 90 percent of labor. Whether this labor is then without employment is not clear.

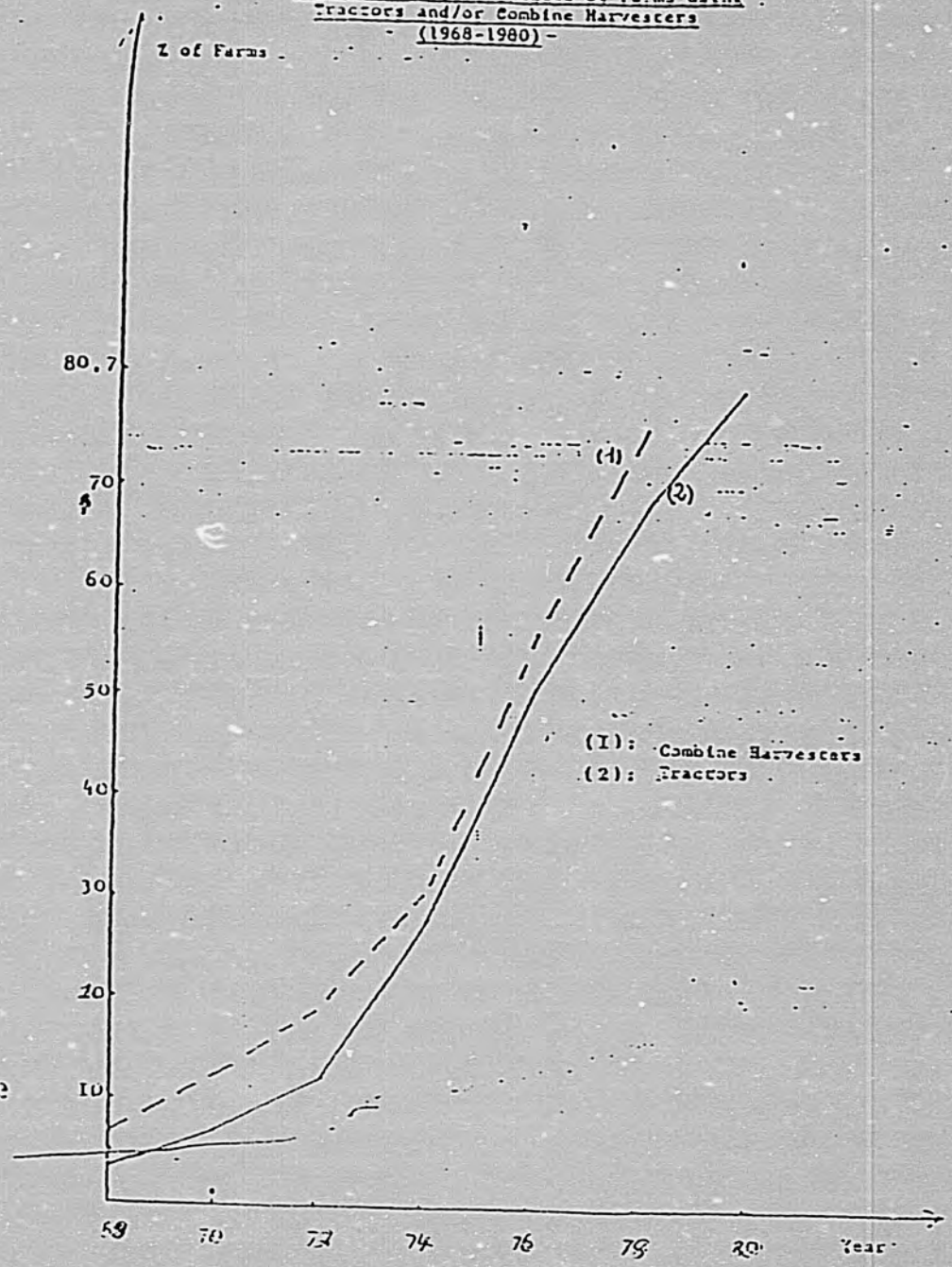
In almost all cases, farms of all sizes except the largest farms, where family labor is not used at all, are characterized both by substantial underemployment of family workers during much of the year and by the hiring of wage workers at peak seasons.

FIGURE 5
Animal Traction and Mechanization Rates for Cumulative Area Farmed by Farm Category

| Category | Animal Traction as % Cumulative Area Farmed | Mechanization as % of Cumulative Area Farmed |
|---|---|---|
| I | 36.6 | 63.4 |
| II | 26.0 | 74.0 |
| III | 35.0 | 65.0 |
| IV | 30.0 | 70.0 |
| V | 23.6 | 76.4 |
| VI | 24.3 | 75.7 |
| VII | 11.2 | 88.8 |
| VIII | 0.1 | 99.9 |
| IX | 5.9 | 94.1 |

Source: Zagdouni, L. La Mechanization en Zone Bour: Cas de la Haute Chaouia, 1981, p. 334.

FIGURE 6
Evolution of Percentages of Farms using Tractors and/or Combine Harvesters (1968-1980)






Reference: Morton, Alice L., "A Beneficiary Profile of Haute Chaouia (Morocco), 1982.

Despite the increasing cost of custom work, there was apparently excess demand for combine services in Haute Chaouia, as elsewhere in the dryland zones during the 1982 harvest, with the cost doubling in some areas during the harvest peak. (See Figure 6 for the evolution of percentages of farms using tractors and/or combine harvesters).

Other energy aspects of agriculture at the farm level in Haute Chaouia were unfortunately not addressed in this survey. Future work should include an investigation to determine other inputs used on these farms, i.e., fertilizers, improved seeds, fuel used in machinery and transportation. Also if any of the irrigated perimeters exist in the dryland area, their energy inputs should also be examined. Yield figures should also be included.

Very little information was available on the fuel used by farm machinery by farm category. Information obtained in aggregated form for farm machinery, including tractors and combines, indicate that this is the largest consumer of direct energy use on the farm with a total usage of 198,500 TEP of diesel fuel in 1980. (See Figure 7 for Patterns of Energy Consumption in Moroccan Agriculture).

Irrigation:

Since this survey only focused on dryland farms, the pattern of energy use for irrigated farms was not included in the farm classification data. Although specific data for Morocco was not available, the magnitude of energy usage on irrigated land is generally much higher than that for dryland agriculture. Additional energy may be required for irrigation pumping, and in many cases, additional tillage operations and fertilizer inputs are necessary. In the U.S., as much as a fivefold energy increase may be required for an irrigated corn crop in comparison to corn produced in a dryland situation. See Figure 8 for further information concerning energy use and corresponding yields differences in Kansas agriculture.

Permanent irrigation covered an estimated 1,060,000 hectares in 1980 consisting of the large-scale irrigation sector (LSI perimeters) of the irrigation perimeters and small and medium-scale irrigation (SMSI perimeters) in the dryland areas. The greater part of the permanently irrigated land (560,000 hectares) is in the large-scale irrigated perimeters.

Information was not available on the specific systems used by various farms, i.e., gravity, sprinkler, trickle, etc., in order to determine energy use. However in looking at some aggregated energy consumption figures calculated for the agricultural sector, energy use for irrigation in direct fuel usage appears to be the second largest category after farm machinery use in Morocco.

Irrigation pumping in the LSI perimeters consumed an estimated 52,400 TEP in 1980, 89 percent of it being electricity. Electricity was provided by relatively low-cost grid generated by hydroelectric and thermal stations.

Figure 7: PATTERNS OF ENERGY CONSUMPTION IN AGRICULTURE (1980)

| Segment/Energy Application | 1980 Unit | 1980 Quantity | Energy Consumption 1980 Quantity (TEP)* | Energy Consumption 1980 Fuel Type |
|---|---|---|---|---|
| LSI perimeters | | | | |
| Irrigation Pumping[1] | Hectares | 100,800 | 5,100<br>41,300 | Diesel<br>Electricity |
| Farm machinery[2] | Tractors<br>Combines<br>Miscellaneous machinery | 10,300<br>907<br>n.a. | 107,600 | Diesel |
| Livestock/poultry[3] | Milk collection stations | 200 | 198 | Electricity |
| | Other | n.a. | n.a. | Propane<br>Butane<br>Electricity |
| Rainfed zones | | | | |
| Irrigation pumping[4] | Ha (zones of State inter.) | 35,800 | 16,500 | Diesel |
| | Ha (private initiative) | 100,000-165,000 | 46,000-75,000 | Diesel |
| Farm machinery[5] | Tractors<br>Combines<br>Misc. machinery | 13,110<br>1,155<br>n.a. | 100,400 | Diesel |
| Livestock[6] | Isolated | Few | Negligible | Diesel |
| Both Sectors Fertilizer | Nitrogen (M.T.)<br>Other fertilizer (M.T.) | 80,000 | 107,500 | Natural gas<br>Oil<br>Electricity |
| | $P_2O_5$ $K_2O$ | 117,000 | 35,000 | |

Reference: Sited in Andrew McWilliams, Energy Demand Study Draft Report), Kearney Inc. for USAID, 1984.

Footnotes: Located on following pages #1-6 taken from McWilliams, #7 are derived from fertilizer information using USAID sources and converted to energy values given in David Pimental, Handbook of Energy Utilizer in Agriculture, CRC Press: Boca Raton, Florida, 1980.

*TEP = Tons of Petroleum Equivalent, a measure which ranges in value from about 8.6 to 11.0 million kilocalories (0.84 to 1.08 TOE) depending on the type of energy being measured.

Figure 7 (cont'd)

ENERGY CONSUMPTION IN AGRICULTURE (1980)

Notes:

1. Provisional estimates; data promised but not yet received from MARA.

2. The total Moroccan tractor stock in 1979 was 22,420, of which 44% (9,864 tractors) were used on LSI perimeters. (MARA, La Situation Actuelle du Secteur Agricole, August 1980, (p. 164). New tractor sales in 1979 were 2,489 (ibid., p. 164) which, in combination with an estimated attrition of 1,500 (World Bank, Memorandum on Morocco's Agricultural Sector, May 1980, p. 23), gives an estimated 1980 inventory of about 23,409 tractors, of which 10,300 (44%) are assumed to have been used on LSI lands.

Data specific to the Haouz LSI perimeter (Charat, October 20, 1983) show and average energy consumption of 10 tons of diesel fuel per tractor, but an average of 12% of all tractors is non-operational. Adjusting the average per tractor fuel consumption downward to account for non-operationl machines gives an average energy use coefficient of 8.9 TEP/tractor (10 x .89).

Multiplying the total tractor stock on LSI lands (10,300) by 8.9 TEP gives an estimated total energy consumption of 91,670 TEP of diesel fuel.

A similar approach was employed to estimate total energy consumption by combines, substituting the following data: 2,100 combines in 1978 (World Bank, Memorandum, p. 23); sales of 236 units in 1978, 126 units in 1979 (MARA Situation; estimated depreciation of 200 units/year (World Bank, Memorandum, p. 23); 44% of combines assumed used on LSI lands (like tractors); average fuel consumption 14 tons diesel fuel per combine (Charat); average of 17% of combines broken down (ibid.).

No estimates are available of other, miscellaneous farm machinery fuel, but consumption estimate for tractors plus combines was raised 5% to account for them (same procedures are used in a recent study of energy consumption in the Egyptian agricultural sector, i.e., U.S. Department of Energy, Joint Egypt/United States Report on Egypt/United States Cooperative Energy Assessment, Vol. 3, April 1979, p. 31.).

3. Number of milk collections stations estimated at about 200 in 1980, most of them located in LSI perimeters, based on data in World Bank, Memorandum, pp. 69-70. Data on 33 stations in Haouz LSI perimeter (Charat) indicates average energy consumption on 11,576 kwh, which yields a total energy consumption of 2.3 million kwh when applied to all 200 stations. At 860 kcal per kwh, total energy consumption expressed in TEP is about 198 TEP.

4. SMSI areas of State intervention total about 215,000 ha, of which 35,800 ha use pump irrigation (Lahrech, October 27,1983). Energy consumption per hectare of pump-irrigated land based on data for Marrakech region (Germoumi, October 20, 1983).

Energy consumption for irrigation on SMSI areas of private initiative estimated as follow. Lower-bound estimate extrapolated from land-use data in World Bank, Staff Appraisal Report of the Small and Medium Scale Irrigation Project, February 1983, pp. 5-6. Upper-bound estimate based on approximately 275,000 small engines and windmills used for irrigation pumping (extrapolated from 1973-1974 Recensement Agricole) and average irrigated tract of 0.6 ha on small farms under 10 ha (ibid.) i.e., 275,000 x 0.6 = 165,000. Energy use coefficient per ha same as that used in SMSI areas of State intervention.

5. See note 2; remaining 56% of tractors and combines are used in rainfed zones. Average tractor energy consumption based on data for Marrakech region, i.e., 6.24 TEP diesel per tractor (Germoumi). Average combine energy consumption in rainfed zones unavailable; figure used is average for LSI perimeters (see note 2). Add 5% to total energy consumption for miscellaneous machinery.

6. Average fuel consumption per diesel pump used for livestock watering based on data in Steingass and Asmon, Market Assessment of PV Systems for Agriculture in Morocco, September 1981, pp. 6-12.

7. 80,000 Metric tons of Nitrogen fertilizer and 117,000 Metric tons of other fertilizers ($P_2O_5$ $K_2O$) were in Morocco in 1980 (Richard Newburg, per design work for a USAID fertilizer Project in Morocco).

According to figures from David Pimentel's Handbook on Energy Utilization in Agriculture, the total energy input for nitrogen fertilizer (taking an average for anhydrous ammonia, urea, and ammonia nitrate) including production transportation, storage and transfer is 13.7 Mcall/kgN. (or $13.7 \times 10^6$ cal/KgN).

$$80{,}000 \text{ M.T. } n \times \frac{1000\text{kg}}{\text{M.T.}} = 80 \times 10^6 \text{ kg or}$$

$$80 \times 10^6 \text{ kg} \times \frac{13.7 \times 10^6 \text{ cal}}{\text{kgN}} = 1096 \times 10^{12} \text{ calories}$$

or $1096 \times 10^9$ Kilo calories N.

1 Ton of crude oil equivalent (TOE) = 10.2 million kilocalories from the World Bank report, Morocco: Issues and Options in the Energy Sector.

$$1096 \times 10^9 \text{ KCN} \times \frac{1 \text{ TOE}}{10.2 \text{ million KC}} = 107.5 \times 10^3 \text{ TOE}$$

or 107,500 TOE.

The Energy Input for phosphate ($P_2O5$) and Potash Fertilizers ($K_2O$) were calculated for production transportation of raw materials and the transportation and distribution of find products as 2.1 Mcal/Kg.

$$117{,}000 \text{ M.T.} \times \frac{1000 \text{ Kg}}{\text{M.T.}} = 170 \times 10^6 \text{Kg PK}$$

$$170 \times 10^6 \text{ Kg PK} \times \frac{2.1 \times 10^3 \text{kc}}{\text{Kg PK}} = 357 \times 10^9 \text{ KC}$$

1 Ton crude oil (TOE) = 10.2 million KC

$$357 \times 10^9 \text{ KC PK} \times \frac{1 \text{ TOE}}{10.2 \times 10^3 \text{ Kc PK}} = 35 \times 10^3 \text{ TOE or } 35{,}000 \text{ TOE}$$

FIGURE 8

IRRIGATED AGRICULTURE
ENERGY INPUTS PER HECTARE FOR IRRIGATED CORN IN KANSAS

| Item | Quantity/ha | kcal/ha |
|---|---|---|
| **Input** | | |
| Labor | 10.39 hr | - |
| Machinery | 55 kg | 990,000 |
| Gasoline | 29.11 t | 294,273 |
| Diesel | 86.31 t | 985,142 |
| Electricity | 125.96 kWh | 363,486 |
| Nitrogen | 185.03 kg | 2,220,360 |
| Phosphorus | 39.25 kg | 117,750 |
| Potassium | 11.24 kg | 17,984 |
| Seeds | 20.21 kg | 505,250 |
| Irrigation | 53.34 cm | 1,023,491 |
| Natural gas | 1138.09m$^3$ | 13,444,257 |
| Herbicides | 2.17 kg | 212,930 |
| Drying | 4791.43 kg | - |
| Transportation | 170.41 kg* | 43,795 |
| Total | | 20,435,523 |
| **Output** | | |
| Total yield | 6838.44 kg | 23,820,264 |
| Protein yield | 609.10 kg | 2,436,400 |
| kcal output/kcal input | | 1.7 |
| kcal output/labor hour | | 2,301,475 |

*Fuel, seed, and machinery.

NON-IRRIGATED AGRICULTURE
ENERGY INPUTS PER HECTARE FOR CORN PRODUCTION IN KANSAS

| Item | Quantity/ha | kcal/ha |
|---|---|---|
| **Input** | | |
| Labor | 7.34 hr | - |
| Machinery | 55 kg | 990,000 |
| Gasoline | 26.96 t | 272,539 |
| Diesel | 54.95 t | 629,199 |
| LP gas | 2.06 t* | 15,872 |
| Electricity | 126.96 kWh | 363,486 |
| Nitrogen | 110.46 kg | 1,325,520 |
| Phosphorus | 23.54 kg | 70,620 |
| Potassium | 10.10 kg | 16,160 |
| Lime | 78.50 kg | 24,763 |
| Seeds | 13.68 kg | 342,000 |
| Insecticides | 2.32 kg | 201,632 |
| Herbicides | 1.41 kg | 140,873 |
| Drying | 1107.92 kg | - |
| Transportation | 136.82 kg* | 35,163 |
| Total | | 4,427,825 |
| **Output** | | |
| Total yield | 2992.63 kg | 10,424,186 |
| Protein yield | 266.51 kg | 1,066,040 |
| kcal output/kcal input | | 2.35 |
| kcal output/labor hour | | 1,420,189 |

*Fuel, seed, and machinery

Source: Handbook on Energy Utilization in Agriculture, David Pimental, CRC Press, Boca Raton, Florida, 1980.

Large scale irrigation projects typically cover between 10-20,000 hectares and involved consolidating fragmented landholdings into economic-sized units. The rest of the pumping requirements were met by diesel-powered pumps.

Irrigated tracts outside the LSI perimeters are predominately small and fragmented. Nationwide, among small farms less than 10 hectares large (which make up 2/3 of all Moroccan farms), the average irrigated parcel was 0.6 hectares at the time of the 1973-4 Recensement Agricole. These tracts used an estimated 52,000 to 86,000 TEP of diesel fuel for irrigation pumping. Irigation pumping on SMSI areas of state intervention consumed as estimated 18,400 TEP of diesel fuel in 1980.

Due to the relatively lower cost and convenience of electricity, users prefer electric pumps to diesels as well as wind and other renewable pumping technologies. However, grid supplied electricity is available in few areas outside the LSI perimeters. Most SMSI pump users therefore use diesel pumps (McWilliams).

Although Morocco has an ambitious national rural electrification program, it is not expected to have a major impact on the nationwide use of diesel pumps. Some alternatives to diesel pump use will be discussed in a later section.

Livestock:

The third and minor category of direct energy appears to be associated with the livestock/poultry with an estimated 198 TEP used in 1980. Modern, intensive livestock raising activities are operated primarily for the benefit of high-income farmers and cooperatives in the large irrigated areas.

Fertilizers:

All fertilizers except phosphorus are imported. (Three-quarters of the world's known phosphate reserves are said to be in Morocco. Phosphate fertilizers are manufactured domestically). The Strategy Paper mentions that nitrogen fertilizer and quality seed have been short of needs. While being unable to find data for Morocco concerning fertilizer use by farm size and yield, it has been well documented that improved technology such as this is directly related to yield increases. The AID paper states that only 7 kg of nitrogen are used on average per hectare, compared with an apparent need of about 40 kg per hectare. Fertilizer is estimated to be the largest energy input into Moroccan agriculture. Refer to Figure 7 for specific information on these energy calculations.

## IV. AID PROJECTS AND ENERGY NEEDS IN AGRICULTURE

Agricultural project papers, Country Development Strategy Statements (CDSSs) and Agricultural Sector Strategy papers, etc. were reviewed to determine which energy concerns were being addressed by AID agricultural projects. Energy projects papers were reviewed for their agricultural implications. This section summarizes the findings from this review.

### Agricultural Projects:

#### 1. CDSS - Agricultural Sector Strategy Paper (FY1984):

The CDSS does not address the subject of direct fuel usage and availability for the transport of agricultural inputs or for machinery use on the farm. However, the paper does discuss such issues as improved seeds, fertilizer, herbicides, improved farm machinery and tillage methods, forage production for livestock. The major energy use components are described as follows:

a. Irrigation - 1) States the need for the investigation of increasing water use efficiency in irrigation systems; 2) need to develop optimal crop-livestock systems in irrigated perimeters without reducing production of high value crops such as fruits and vegetables. There is no mention of fuel required or increased energy inputs required for operation of irrigation systems.

b. Small-Scale Mechanization - Says that increased tractor use seems to be stagnating despite low prices for tractor diesel fuel. Mentions importance of developing improved tillage equipment for both machinery and animal applications.

c. Fertilizer - States that it is generally believed to be only 1/4 of the amount needed for optimal crop production under currently known technology. Recommendations are made for future programming efforts in this area to increase fertilizer supply and distribution.

#### Morocco CDSS (FY 86)

In the this recent CDSS, the rainfed sector emphasis formulated in late 1981 is re-examined. The original assumptions underlying the Rainfed Strategy were based on three items: 1) other donor participation in the irrigated perimeters 2) rainfed agriculture would contribute to the larger number of beneficiaries and 3) that the U.S. had greater depth of transferable experience in dryland cereal production.

This 1981 strategy has been reassessed in the light of 1984 economic realities which include drought conditions going into a fourth year, lack of a

substantial, proven technological package that can be effectively extended to farmers in the rainfed sector, and the momentum of existing irrigation projects on one hand and large cuts in development and operating budgets of the Ministry of Agriculture, have reduced GOM's options for a major reallocation of resources.

Due to the vagaries of weather, it seems that energy-intensive irrigated agriculture will continue to play an important role in contributing to food and export production in Morocco.

2. Dryland Agriculture Applied Research, Project Paper Amendment #3, Project No. 608-0136, August, 1983.

This research project, according to the CDSS, is being accelerated and expanded with the addition of a agricultural machinery specialist to carry out a small-farmer mechanization component. This will include a range of activities that will be directed towards improving cultivation, planting and fertilizer application practices through the development of better tillage equipment for animal tractions and tractors. The Project Paper did not mention increased energy requirements generated by this mechanization program.

A forage agronomist is provided to carry out research on the provision of adequate high-quality feed for livestock and to examine alternative forage systems. Lack of forage in Morocco is the principal limiting factor to livestock production. The majority of animals are undernourished.

A rural sociologist has been included to provide a direct link between the agronomic, economic, and sociological research activities. It is important that this person also examine energy inputs into the farm system in the 51 Farm Survey. It was under this project that the detailed work on human/animal/machinery component of the farm classification system was done. More information needs to be included in a similar survey to examine farm energy use.

Other marginally energy related goals include: 1) concentration on the development of drought-tolerant and higher yielding barley species and 2) determination of whether or not N, P, and K singly or in combination can be economically used and in what circumstances.

3. Agronomic Institute (#608-0160):

The main purpose of this project is to complete the development of a modern college of agriculture appropriate to Moroccan agricultural development. The faculty is being trained in various disciplines. As of 1980, no one was being trained in Forestry or Food Technology.

4. Planning, Economics, and Statistics for Agriculture, #608-0182:

More accurate and timely data collection pertaining to agricultural statistics and analysis required for improved policy decisions is the goal of this project.

There is no mention of any statistics or surveys being carried out to look at energy use in agriculture specifically although envisioned survey include the areas of irrigation, agro-industrial use, livestock, etc. Nothing is mentioned pertaining to fertilizer use, seeds, etc. Further information on this project is discussed in the section on Project Design Considerations.

5. Range Mangement Improvement Project, (#608-0145):

This project is essentially aimed at vegetative regeneration and the improvement of rangeland. No energy aspects are especially discussed. However, fuel will be a requirement for farm operations to seed range grasses. Also weed control and fertilizers will be needed to produce wheatgrass seed on a 100 hectare seed farm.

The GOM will pay for the Range Program Operating Budget including shelters, ponds, etc. Nothing is mentioned on the payment for fuel and fertilizers but it is presumably included under the GOM's costs. Intensive rangeland management will require additional energy sources for seeds, fertilizers, farm operations, etc. The lack of commercial energy for these purposes could be a barrier to good rangeland mangement and is not discussed.

It was observed by a recent evaluation team (Furtion et al.), in the project area that there is a lack of fuelwood and consequently forage plants are being used for fuel. Although the question was raised but not looked at specifically, it is unknown to what extent the use of range plants as fuel is contributing to the lack of forage and land degradation, i.e., it may be that the plants used are older and are not satisfactory for feed. It might be useful in cases such as these to have a biomass expert assess the situation.

6. Doukkala - Zemamra Irrigation Project:

This project included the construction of 4 pumping stations with necessary power connections to provide sprinkler irrigation for high value crops such as sugar beets. Very little mention was made regarding energy requirements for irrigation pumping. Further information pertaining to the project energy supply, quantities used, user charges, are discussed in the section on Project Design Considerations. Other energy inputs to the project included increased use of fertilizers and improved seeds. Both mechanization and animal traction were to be utilized.

Energy Projects:

1. Renewable Energy Development Project (#608-0159):

Possible agricultural applications of energy technologies described in this report for research and pilot projects include the use of small-scale hydro, wind, and photovoltaics. These can be used for irrigation, providing water for livestock, providing refrigeration for centralized crop storage and fish preservation. There are many other potential uses of electricity for

motors, grain milling, etc. The Biomass Conversion component includes biogas, gasification, pyrolysis, and densification to produce fuel pellets.

This project has funded a recent study on the market potential for renewable energy technologies in Morocco (McWilliams). The economics of energy inputs and their possible substitution for diesel and a central grid network for water lifting are examined further in Figure 11.

2. Conventional Energy (#608-0176):

This project is to strengthen and accelerate Morocco's indigenous oil and gas exploration programs. This could have energy implications for agriculture in the future.

3. Energy Planning (#608-0180):

This project will assist in transferring and institutionalizing the use of analytical and econometric techniques to the Ministry of Energy and Mines providing advice directly to the decision-makers responsible for GOM energy policy, pricing structures and investments.

The predecessor to this project was the S&T project entitled Energy Policy Development and Conservation (936-5728) which aimed to strengthen the institutional capacity of Morocco's Ministry of Energy and Mines in the area of energy planning analysis.

## Discussion of Research Needs and Current Project Activities in the Agriculture/Energy Interface

Specific portions of these project papers were classified by agricultural inputs, i.e., machinery, fertilizer, pesticides, seed propogation, and water for irrigation, needed for agricultural production; along with other components of the agricultural system such as transportation, processing, and food preparation to determine whether projects were addressing particular needs in the food system and if not, what gaps could be identified. The results of that exercise are depicted in Figure 9.

In general, the agriculture and energy portions of the AID project portfolio cut across many problems that related to the food and energy system. The agricultural projects, as could be expected, concentrate only on

FIGURE 9

ENERGY AND AGRICULTURE ISSUES IN OF MOROCCO AID PROJECTS

| PRODUCTION AGRICULTURE | ISSUES - ENERGY/AGRICULTURE | HOW ADDRESSED (OR NOT) |
|---|---|---|
| Farm Machinery | Development of improved equipment for both animal traction and tractors to increase soil moisture retention, and improve efficiency of fertilizer and seed use. | Dryland Agriculture Applied Research Research Project: Small Farm Mechanization Component |
| | How much energy will be required? Cost? Sources? etc. | Not addressed. |
| Animals | Better nourishment of livestock for animal traction. | Range Management Improvement Project: to increase food production |
| Fuel-Diesel | Existence of fuel supply shortages affecting farmers? | Not addressed. |
| | What alternatives (if any) exist to the usage of fossil fuels in tractors? | Use of bio-gas in tractors discussed under a study commissioned by CDER |
| Fertilizer | Methods to increase fertilizer use and efficiency | Dryland Agriculture Applied Research Project. |
| | Insure that all farmers have continuous access to fertilizers. It is estimated that only 1/4 of the amount needed for optimal crop production under current technology is being used. | No current project. However, this need was mentioned in the CDSS - Agriculture Strategy Paper. Some project design work in this area was included in the Planning, Economics, and Statistics PID but was not includedin the final project. Mission seems to be thinking in the direction of developing a project in this area |
| | Very little is known on fertilizer use and yields. Need for data collection. | No current work being done in this area. |
| | Organic fertilizer production from biogas slurry | Renewable Energy Development II Project |

| | | |
|---|---|---|
| | Nitrogen Fixation | No current projects |
| | Feasibility of alternatives in production of N and N/P products including local gas, other feedstock or imported $NH_3$ (ammonia) | No current projects. Mentioned in some early project design work in this area. |
| | Study of market development and constraints farmers are facing in using fertilizer. | |
| Pesticides | Possibility that better access to pesticide could be addressed in conjunction with a fertilizer supply and distribution program | No current projects. Mentioned in the CDSS - Agriculture Sector Strategy Paper |
| Seed Propagation | Seed production for reseeding of range grass | Range Management Improvement Project (a 100 hectare seed farm is included) |
| Water Irrigation | Need for research on increased water use efficiency | Discussed in CDSS - Agricultural Sector Strategy Paper |
| | Need for information on energy requirements of irrigation systems. costs? sources? etc. | Not addressed. No discussion of fuel or energy source used in an evaluation of an AID irrigation project, i.e., An Assessment of the Lower Moulouya Irrigation Project nor in a sprinkler irrigation system in use with 4 electrically powered pumps, i.e., Doukkala-Zemamra Sprinkler Irrigation Project |

| | | |
|---|---|---|
| | Very little is known about the quantity of energy used in irrigation systems in Morocco | A study with some information on energy usage in irrigation has been done under the Renewable Energy Project for the Center of ? (CEDER)<br><br>Data pertaining to irrigation systems and their energy usage could be collected uder the Planning, Economics, and Statistics Project. |
| Irrigation<br>Livestock | Investigation of alternatives to diesel pumping in off-grid areas. Preliminary studies being done comparing wind and PV--costs and benefits. (See Figure 11 for further information.) | Renewable Energy Project in CDER papers by Andrew McWilliams and<br><br>Allan Wyatt. |

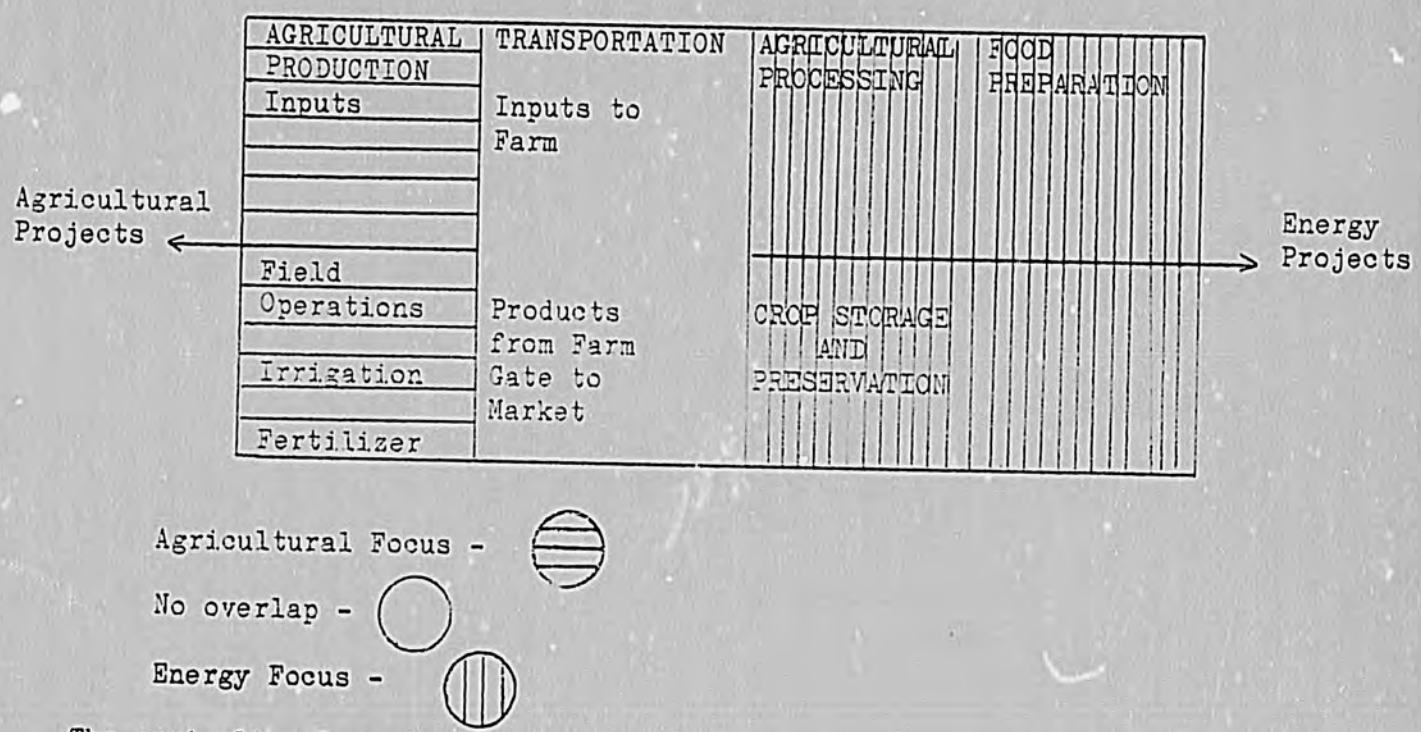
## ENERGY AND AGRICULTURE ISSUES IN MOROCCO AID PROJECTS

| OTHER COMPONENTS OF THE FOOD SYSTEM | ISSUES - ENERGY/AGRICULTURE | HOW ADDRESSED (OR NOT) |
|---|---|---|
| Transportation | What bottlenecks related to transportation fuel usage exist in getting inputs to the farm Do fuel supply limitations restrict access farmers have in getting their crops to market? | Very little in known about energy usage in transportation pertaining to agriculture. Some information on energy use in transportation has been done under the Energy Policy Development and Conservation project by $E^3I$. |
| Agricultural Processing | Some renewable applications seem to be available, i.e., gasification of olive pits for use in fueling boilers in olive processing plants<br><br>Similar research may be needed in increasing energy efficiency in tomato processing plants, milk processing, etc. | The Renewable Energy Project has a fund available to private entrepreneurs and others for projects in this area. |
| Crop Storage and Preservation | Energy is needed in food systems for crop storage and preservation. | This subject is addressed somewhat in the Renewable Energy Project and includes PV powered refrigeration for centralized crop storage and fish preservation. |
| | More information is needed on the energy requirements for this food component in Morocco. | Some information in this category is addressed in the report done by $E^3I$ for the Energy Policy Development and Conservation Project. |
| | Extent of food loss due to lack of energy requiring systems such as refrigeration. | Not addressed. |
| Preparation of Food | Better methods are needed to reduce energy consumption in home preparation of food especially pertaining to fuelwood usage in cooking. | Work in this area is being done under the Renewable Energy Project which is funding work on more efficient stoves, and kilns for charcoal production. |

the production aspects of agriculture; whereas the energy projects include areas concerning agricultural production, processing, and preparation of food. Transportation as a component of the food system has seemingly been neglected by the two sectors as illustrated in the following chart:

Figure 10.

Energy and Agriculture Interface in Moroccan AID projects in the Examination of the Entire Food System.




The agricultural projects primarily focused on the agricultural production system concerning energy-related inputs such as machinery, improved seeds, and water for irrigation. There are not any specific projects concerning the use of fertilizers and pesticides in Morocco although the Mission has indicated interest in this area for future programming. Specific issues of fuel and energy to operate these inputs were often overlooked by AID project designers and contractors.

The transportation aspect of the food system was neglected by both agriculture and energy projects although some general work on transportaton has been done under the centrally-funded S&T/Energy Policy Development and Conservation Project. No information was currently available on specific energy use in tranportation related to agricultural needs.

The Renewable Energy Project (REP) had some overlap concerning the food system in agricultural production, i.e., the possibility of substituting renewables for fossil fuels to pump water for irrigation and livestock, and the production of organic sources of fertilizer from biogas systems. Other aspects of the Renewable Energy Project related to agricultural processing and preparation of food which were not covered by the agricultural projects. Some renewable energy applications were thought possible in agricultural processing

plants such as in the gasification of olive pits for use in fueling boilers, etc.; in PV powered refrigeration for centralized crop storage and fish preservation; and the REP is also supporting effort to reduce energy consumption for home preparation of food primarily to make more efficient use of fuelwood.

## V. PROJECT DESIGN CONSIDERATIONS - EXAMINATION OF ENERGY ALTERNATIVES AND MORE COST-EFFECTIVE SUPPLY OPTIONS

Development planners need to be cognizant of energy use considerations in order to select the most appropriate energy sources in projects. Some recommendations for general project design have recently been included in Handbook 3 (Appendix 3-0) entitled, "Analysis of Energy Use and Prodution in Projects." It discusses, among other topics, comparing energy inputs per unit of output produced as a method to rank energy use types. This may be possible if the production of an agricultural commodity is involved, however, in many AID projects, it may be difficult to relate energy use to tangible outputs especially if it concerns a training or research project.

Following is a brief attempt to examine what possible energy options could have been considered for an irrigation project. In examining the Doukkala-Zemamra Sprinkler Irrigation Project (#608-0127) as an example of selecting energy choices in agricultural projects, the project's stated purpose is to establish irrigated agriculture on 15,410 hectares in the Doukkala region. The sector goal is to increase agricultural production for import substitution and for export.

The Handbook recommends that the project's inputs and outputs similar to that stated in a Logical Framework be examined to determine what energy sources will be consumed and/or produced. By analyzing the stated inputs and magnitude of outputs, we can determine that energy will be required for several components as follows:

1. Irrigation in 4 sections

2. 3 community centers built and staffed;
   6 milk collections stations built

3. 193 km roads built; 50 km telephone lines operational connecting 7 village centers with roads, electricity, water and schools

Nothing was mentioned in the project about the energy needed for the construction of roads, irrigation systems, pumping stations, extension of telephone lines, etc. In the irrigation component, it was determined that a sprinkler irrigation system should be used due to irregular surface and soil type involved which did not permit land leveling for a gravity-flow system.

The project built an extension (50 km.) of a 60kV/20kV line to receive electricity from a centralized on-grid system. It was planned that 4 pumping stations with a combined installed capacity of 8300 kW would supply water from a main canal into underground networks and hydrants, each covering 16 hectares served by movable equipment.

It would have been useful if the project paper had included some estimates using different energy systems although it appears that on-grid electricity is still one of the lowest cost options for the Doukkala area. Due to the close proximity of the electrical grid system, it appears that the provision of decentralized power for pumping provided by diesel, photovoltaics, wind, etc. may not have been appropriate and also could have been more costly. (Estimates are given comparing the cost of different technologies for water pumping in Figure 11). However, an explanation as to why the energy choice selected was the best under the project circumstances involved would have been beneficial.

Scarce resources and foreign exchange limitations should also be discussed to rationalize the choice of a particular energy source. The extent that foreign exchange earnings were involved in the production of electricity used by this project depended on the energy resources utilized by the generating station , i.e., 64 percent of electricity production is thermal, generated from oil and coal (very small proportion), and 36 percent is hydroelectric. (Renewable Energy Project II Paper: p. 12).

Farm budgets for four farm categories were analyzed in the project paper and in all cases, net farm income was foreseen to substantially increase after the project, which would cover the increased energy inputs in the form of irrigation, mechanization, fertilizers, and seeds. No specific discussion was included regarding the payment of recurrent energy costs such as water user charges, electricity used in the milk collection stations, etc. by the project beneficiaries. Practically no information was included pertaining to who would pay for the energy inputs or their costs.

While the energy choice selected may not have changed dramatically after an energy analysis was performed, it would have been highly beneficial to examine the overall efficiency of energy use choices as well as relate them to both the national energy scenario and the individual user situation.

Not all projects will have a direct energy use or production comparison (comparing energy inputs to yield increases), taking for example, the Planning, Economics, and Statistics for Agriculture (#608-0182). The project purpose is to improve the GOM's ability to collect agricultural statistics, undertake economic analysis and monitor and evaluate agricultural projects.

The overall program goal is to make available current information and sound analysis that will enable GOM officials to make policy decisions that will lead to increased agricultural production.

# FIGURE 11

USER CONSIDERATIONS: WATER PUMPING

| Pump Type | Capital Cost | Fuel Cost | Cost per $M^3$ Water Pumped | Maintenance Requirements/ Reliability | Flexibility | Risk | Socio-cultural Considerations | Other |
|---|---|---|---|---|---|---|---|---|
| 6.25 HP diesel w/pump | $ 3,200<br>DM 25,000 | $ 0.39/l<br>DM 2.81/l | $ 0.02[1]<br>DM 0.16 | High maintenance requirements; relatively frequent breakdowns; short life | Suitable up to very large pumping applications | Commercial, mature technology | | High domestic manufactured content; imported fuel |
| 5 kw AC electric motor w/pump | $ 2,700<br>DM 21,000 | $ 0.06/kwh<br>DM 0.45/kwh | $ 0.01[2]<br>DM 0.08 | Prime mover (motor) reliable, but electricity supply often not | Suitable up to very large pumping applications but tied to electricity supply | Commercial, mature technology | | High domestic manufactured content |
| 3.3 kwp PV array with pumpset and reservoir | $ 63,000<br>DM 300,000 | None | $ 0.11[3]<br>DM 0.86 | Potential for long life and low maintenance | Limited to areas of shallow water table, low water requirements | Commercial, not mature | Unfamiliar technology | PV array (most of capital cost) imported |
| Aeromotor-type wind pump | $ 2,300-<br>$ 7,600[4]<br>DM 18,000 - 59,000 | None | $ 0.02-0.27[5]<br>DM 0.16 - 2.1 | Relatively high maintenance; lack of repair service and spare parts | Similar to PV | Commercial, mature | Unfavorable perception based on past experience | Limited domestic manufacturing capacity, but most units imported |

All prices are 1983 prices, except as noted
Nov 1983 exchange rate: US $1 - DM 7.8

Detailed Footnotes on following pages

Source: Energy Demand Study, Andrew McWilliams, Kearny Inc., for USAID, 1984. (Table and Footnotes)

Figure 11

USER CONSIDERATIONS: WATER PUMPING

Notes:

1 Installed cost of 6.25 HP diesel pump and diesel fuel costs provided by M. Haouti, ORMVA Souss-Massa (November 15, 1983). Other assumptions and analysis after
Harry Steingass and Etil Asmon, Market Assessment for Photovoltaic Power Systems for Agricultural Applications in Morocco, September 1981, p. 6-6, as shown below:

| Item | Initial Costs, $ | Discounted Costs, $ |
|---|---|---|
| 6.25 HP diesel motor with pump | 3,200 | 3,200 |
| Overhaul, end year 3 (60% of purchase price) | 1,920 | 1,253 |
| Overhaul, end year 5 including value seat change -- 70% of purchase price | 2,240 | 1,114 |
| Overhaul, end year 8 (70%) | 2,240 | 732 |
| Replacement, end year 10 | 3,200 | 790 |
| Overhaul, end year 13 (60%) | 1,920 | 312 |
| Overhaul, end year 15 (70%) | 2,240 | 275 |
| Overhaul, end year 18 (70%) | 2,240 | 181 |
| Check injectors and injection pump ($60 every 15 mo) | 50/yr | |
| Diesel fuel (1.5 l/h for 1,000 h, at 1983 cost of $0.36/l plus $0.31/l transport charge | 585/yr | 5,052 |
| Oil change, 2.5 l per 100 h at $1.65 l, with filter | 67/yr | |
| Present value of life-cycle costs discounted at 15% | | 12,919 |
| Estimated pumping volume at 30,000 $m^3$ per year | | 600,000 |

Figure 11

USER CONSIDERATIONS: WATER PUMPING

Notes (cont.)

| Item | Initial Costs, $ | Discounted Costs, $ |
|---|---|---|
| Electric AC 5 kw pumpset | 2,700 | 2,700 |
| Replacement, end year 10 | 2,700 | 667 |
| Electricity 5,000 kwh/yr at $0.06/kwh | 300/yr | 2,159 |
| Present value of life-cycle costs discounted at 15% | | 5,526 |
| Estimated pumping volume at 30,000 $m^3$ per year | | 600,000 |

3 Estimated after analysis in Steingass and Asmon, pp. 6-1 and 6-17, but assuming average PV cost of $13/wp.

4 1981 price World Bank, Market Potential for Wind Energy in Developing Countries.

5 Ibid, p. 4-68. Life-cycle costs calculated using 10% discount rate, vs. 15% used elsewhere in this table. While costs are thus not, strictly speaking, comparable, the practical impact of this discrepancy is small because most of the associated costs are incurred in year 1.

In the project, the energy discussion should concern 2 areas: 1) the availability of fuel to carry out the project's data collection goals; for example, in Kenya, it was the author's experience that survey research was often impeded due to the lack of petrol to run project vehicles; and 2) obtaining statistics and carrying out surveys pertaining to energy usage in agriculture. In the project paper there is no mention of energy related data for irrigation, i.e., gravity assisted vs. pumping; for fertilizers, i.e., yields and type of fertilizers being used by crop type or farm size for future planning efforts in this area.

If statistics and surveys do not obtain energy related data, an opportunity will be lost to energy, agriculture, and development planners in their efforts to increase production in the food sector. As mentioned in the introduction, increased investment in energy inputs in the agricultural sector have perhaps greater pay-offs than in other sectors. Knowing where to make wise future investments, i.e., in irrigation, mechanization, fertilizers, etc., will be abetted by the collection of this type of data.

## VI. SUMMARY AND CONCLUSIONS:

### Recommendations for Future Investigation and Emphasis

Some suggestions and areas to look at in the future concerning Morocco (although it can applied on a more general focus) include the following:

1. Increased Use of Nitrogen Fertilizer:

The Agricultural Strategy revolved around the goal of increasing cereal production to reduce the rate of cereal imports in Morocco. It discussed the need to increase the supply and distribution networks for key inputs, especially for nitrogen fertilizer. The Strategy stated that only one fourth of the fertilizer that could be potentially used to increase crop yields under current technology was being used.

Nitrogen fertilizer is the largest energy input (albeit indirect) in Moroccan agriculture. There are no fertilizer production plants in the country and all their supplies are imported (Exploration for natural gas is currently being undertaken in the country may make the production of nitrogen fertilizer possible in the future. It should be looked at jointly by energy and agricultural planners. Currently Morocco is a leader in the production of phosphates). The argument could be made that a country such as Morocco can not afford importing excess nitrogen for carry-over in low rainfall seasons. However, the benefits relative to the costs of a fertilizer strategy could be substantial.

Estimates listed in some pre-project design work indicates that 1 Kg. of nitrogen costing about U.S. 60 cents and applied in medium and high rainfall areas will produce on average, an additional 13.5 kg. of wheat, worth about

$2.70 at CIF prices ($200/M.T.) This is roughly a benefit/cost ration of 4:1 (cited from Economics, Planning and Statistics PID; p. 46; further information regarding a program of this nature including better supply and distribution networks, and alternative methods for nitrogen fertilizer production are elaborated on in the Agricultural Sector Strategy, Technical Appendices, p. E.11).

2. Improved Tillage Methods for Animal Traction and Mechanization:

The Haute Chaouia data on energy use by farm category illustrated the high rate of mechanization in that area. Research in the improvement of tillage equipment for both animal and tractors could aid in increasing the overall efficiency of fertilizers and seeds. Several sources mention that instead of broadcasting, better placement of fertilizer and seeds with a drill would increase yield gains and create some savings in seed use. Other sources mention that plowing is done too deeply thus reducing amount of moisture available for the crop.

The Haute Chaouia data also stated that there was excess demand for harvest combines in the area. There are regional extension centers that provide equipment for use by farmers although it is generally agreed that these centers poorly maintain the equipment and that break-downs are frequent. This could be an area for future private sector involvement since this seems to have been quite effective for custom tractor work.

3. Irrigation

The rainfed zones composed of small and medium scale farmers rely on diesel fuel for water pumping because they are not attached to an electrical grid system. Their estimated use of diesel is 62,500 TEP (a conservative estimate) contrasted with only 5100 TEP of diesel used in the large-scale irrigated perimeters (illustrated in Table 9).

While exact statistics are unavailable, it is probable that there will be an increase in the average commercial energy input per hectare of irrigated land, as more farmers refit existing hand- and animal-powered pumps with mechanical pumps, in order to maximize their productivity.

According to McWilliams, sales of small diesel and electric motors for irrigation pumping have continued to increase, in spite of signs that the supply of additional land suitable for private pump irrigation is nearing its upper limit. He states that the retrofitting process will be accelerated if the draft Ministerial decree providing for 30-40 percent subsidies to assist private farmers in equipping their wells with mechanical pumps is enacted.

Because the rural electrification program is not expected to have a major impact on the nation-wide use of diesel pumps for irrigation, diesel fuel will be an important consideration in any future irrigation project taking place in rainfed areas. In irrigation projects, as mentioned earlier, energy

requirements and examinations of alternative sources of power should be made. A study is in process sponsored by the Renewable Energy Project looking at current renewable energy technology in Morocco that will give information regarding the prevalence of renewable energy technologies for pumping water and other renewables.

The AID Agricultural Sector Strategy (FY 1984) mentions the interest in future work regarding the improvement of water use efficiency. This is an energy-related issue and its examination may ultimately contribute to reducing the amount of energy needed to pump the water. Unfortunately, some of these systems are capital-intensive, such as in drip irrigation.

4. Energy Considerations in AID projects:

A. Type of System Selected:

As illustrated in the Doukkala-Zemamra Irrigation project, very little analysis seemed to have been made on choosing the appropriate energy system. Project designers need to be cognizant of foreign exchange constraints imposed by certain types of energy used in projects, engineering efficiency of the system used, etc. These are discussed in-depth in the Handbook Section entitled, "Analysis of Energy Use and Production in Projects."

B. Recurrent Energy Costs:

In examining the Doukkala-Zemamra Irrigation Project, the recurrent cost issue pertaining to energy was scantily included in the Project Paper. While there was mention of the equity of water user charges, the issue of who would pay for the water use charges and for electricity required to operate the milk collection stations, etc. remained unaddressed.

Recurrent energy costs are often glossed over and may serve as a bottleneck to successful implementation of a project. Often it may be falsely assumed by project designers that host governments and project beneficiaries can absorb these costs. Yet if reliable fuel supplies are not available for tractors, to run vehicles at research stations, etc., the entire project effort may be in vain. This seems unfortunate when fuel costs are relatively quite small in comparison to total project costs.

C. Personnel:

There is starting to be a perceived need to increase communication between energy and agriculture personnel. Often people are compartmentalized by discipline which can in turn lead to disjointed project efforts. This can be avoided by assembling personnel of several related disciplines, whether it be agriculturalists, foresters, biomass experts, energy specialists, etc., in future project design and project reviews.

5. Transportation:

A gap was identified in the transportation component of the food system. This area has not really been addressed by agricultural or energy projects. Whether this means this component is not perceived as a major bottleneck in the agricultural system or it just hasn't been addressed was not clear. Little was seen on the material reviewed concerning road networks, fuel availability problems or farmers access to inputs and markets.

Some work may begin in this area if the Mission were to decide to move ahead with a project on fertilizer use. This would address the input side of transportation concerning fertilizer supply and distribution.

However, there would still be a gap concerning energy needed for transportation to get products from the farm gate to market. These issues could be incorporated into the new Energy Planning project for further analysis.

6. Better Data Collection Pertaining to Agricultural Energy Statistics:

Both agricultural and energy projects are deficient to some extent in their data gathering processes. Often the energy component in agriculture is considered too small to be examined in energy projects and sector studies (this has happened both in AID and World Bank projects examined for Morocco) or the energy used in agricultural processing (especially large-scale) plants is classified as an industrial user and is not considered an agricultural energy consumer.

Agricultural projects should give attention to the collection of data which may shed light on the bottlenecks that the lack of proper energy sources can cause. Data collection and surveys funded under the Dryland Applied Agricultural Research and Planning, Economics, and Statistics projects should be examined: 1) to allow for addition of components pertaining to the usage of energy inputs by farm size, 2) to increase the knowledge available on how higher energy prices affect farmers, 3) to determine the potential for substitution of alternative sources (depending on the price elasticities of fossil fuels), 4) to obtain fertilizer usage data by farm category and 5) obtain data on energy used in irrigation so as to determine possibilities for substitution of alternatives.

A survey similar to the one reviewed in this report (Morton, 1982) could include the aforementioned information requirements relevant to agriculturalists and be helpful in energy planning as well. Data is also needed for other components of the food system such as transportation (mentioned above), agricultural processing, and in crop preservation and storage.

It is hoped that these findings will prove useful in identifying and refining future research areas and AID programming needs.

## BIBLIOGRAPHY


1. Agency for International Development, "Analysis of Energy Use and Production in Projects, 1982." Handbook #3, Chapter 3, Appendix 3-0.

2. Agency for International Development, Annual Budget Submission: FY 1985 - Morocco, AID, Washington, D. C., 1983

3. Agency for International Development, Agriculture Sector Strategy Paper, Annex 1, Country Development Strategy Statement - Morocco, FY 1984, 1982.

4. Agency for International Development, Agricultural Sector Strategy paper, Technical Appendices, Country Development Strategy Statement - Morocco FY 1984, 1982.

5. Agency for International Development, Agronomic Institute Project Paper - Morocco (#608-0160), Washington, D. C., 1980.

6. Agency for International Development, Dryland Agriculture Applied Research - Morocco (#608-0136), Project Paper Amendment #3, 1983.

7. AID/Ministry of Energy and Mines, Energy Planning Assistance for the Ministry of Energy and Mines - Government of Morocco, Vol. I, Perspectives on Moroccan Energy Demand and Supply, Vol. II, Moroccan Energy Data Base, Rabat, Morocco, 1982.

8. Agency for International Development, FY-1986 CDSS for Morocco, USAID/ Morocco, 1984.

9. Agency for International Development, FY 1985 - CDSS for Morocco, USAID/Morocco, 1983.

10. Agency for International Development , Planning, Economics & Statistics for Agriculture - Morocco, Project Paper (#608-0182), , 1983.

11. Agency for International Development, Rainfed Agriculture Project: Morocco (#608-0170), Project Identification Document, 1983.

12. Agency for International Development, Range Management Improvement Project Paper (#608-0145), 1980.

13. Agency for International Development, Renewable Energy Development II, Project Paper (#608-0159), 1981.

14. The American University, Morocco: A Country Study, , Washington, D. C., 1978.

15. Baldwin, Pamela, and Koshel, Patricia, "Energy Problems Confronting Developing Countries: Energy and Economic Development - The Unbreakable Link, Agency for International Development, Bureau for Science and Technology - Energy Division, 1984.

16. Campbell, R. R. et al, Applied Agronomic Research Program for Dryland Farming in 200-400mm Rainfall Zone of Morocco, Mid American International Agriculture Conservation Dryland Farming Team, 1977.

17. Center for Comparative Studies in Technological Development and Social Change, An Assessment of the Lower Moulouya Irrigation Project, University of Minnesota prepared under AID contract AIDINE-C-1507.

18. Center for Renewable Energy Development, "A National Agenda for Renewable Energy Development in Morocco", Marrakech, Morocco, 1983.

19. Clever, Kevin M., The Agricultural Development Experience of Algeria, Morocco, and Tunisia: A Comparison of Strategies for Growth, World Bank Staffing Working Papers, No. 522, 1982

20. Costello, Dennis et al, Market Potential for Wind Energy in Developing Countries, prepared for The World Bank, 1982.

21. Development Sciences, Inc., Defining the Relations Between Energy and Agriculture, submitted to Agency for International Development, Africa Bureau, Special Development Problems, Division, 1984.

22. Furtich, William et al, Evaluation of the Moroccan Rangeland Improvement Project, Agency for International Development, 1984, forthcoming.

23. Fluck, Richard and Baird, C., Agricultural Energetics, University of Florida, Gainesville, by AVI Pulbishing Company, Inc., Westport, Connecticut, 1980.

24. Fraenkel, Peter, The Power Guide: A Catalogue of Small-Scale Power Equipment, Intermediate Technology Group Ltd., England, 1979.

25. Hogan, Edward et al, "Morocco Impact Evaluation - Increase in Cereals Production", Draft Report, Agency for International Development, 1983.

26. The International Rice Research Institute, Economic Consequences of the New Rice Technology, Los Banos, Phillipines, 1978.

27. Kooi, C. F., "Some Aspects of Energy Inputs to Agriculture in Developing Countries," presented at the AID Energy Strategy Meeting at Easton, Maryland on 15-18 August, 1982, Agency for International Development, Washington, D.C.

28. Leach, G., "Agricultural Production: Research and Development Strategies for the 1980's," prepared for the conference (same name) in Bonn, Germany, October 8-12, 1979.

29. Leach, Gerald, Energy and Food Production, IPC Science and Technology Press, Surrey, England,1976.

30. Leigh, J. G. et al, Energy and Development: A Preliminary Analysis for Less Developed Countries, the Mitre Corporation for Agency for Internation Development, July 1979.

31. Leigh, J. G. et al., Energy and Development: Extended Analysis and Implecations, The Mitre Corporation for Agency for International Development, May 1980.

32. Makijani, Arjunand Poole, Alan, Energy and Agriculture in the Third World, Ballinger Publishing Company, Cambridge, Massachusetts, 1975.

33. McCombs, John, "Farm Energy Technology Substitutes in Developing Countries, AGREP Division Working Paper No. 49, prepared for the World Bank, Washington, D.C., August, 1982

34. McWilliams, Andrew, "Energy Demand Study", Draft Report, Kearny Mangagement Inc. for the Center for Renewable Energy Development in Morocco, Alexandria, Virginia, 1984.

35. Miller, George, "Developing a Versatile Farm Tractor", prepared for presentation at 1983 Winter meeting of American Society of Agricultural Engineers, Paper No. 83-5510, December, 1983.

36. Mohr, Penny, Energy and Farm Structure in Kenya, M.A. Thesis, University of Sussex, England, 1981.

37. Pimental, David and Marcia, Food, Energy and Society, John Wiley and Sons, New York, 1979.

38. Pimental, David, Handbook of Energy Utilization in Ariculture, CRC Press, Boca Raton, Florida, 1980.

49. Revelle, Roger, "Energy Use in Rural India," Science, 192: 969-975, 1976.

40. Southworth, Herman, editor, Farm Mechanization in East Asia, The Agricultural Development Council, Inc., New York, N.Y., 1972.

41. Steingass, Henry and Asmon, Atel, Market Assessment of Photovoltaic Systems in Agricultural Applications in Morocco, NASA Lewis Research Center DEN 3-180, Cleveland, Ohio, September 1981.

42. Stout, B. et al, Energy for World Agriculture, Food and Agriculture Organization of the United Nations, Rome, 1979.

43. World Bank, Kingdom of morocco - Staff Appraisal Report of the Small and Medium Scale Irrigation Project, Report No. 4197-MOR, 1983.

44. World Bank, Morocco: Issue and Options in the Energy Sector, Report No. 4157-MOR, 1982.

45. World Bank, World Development Report, 1983: World Economic Research and Prospects for Recovery, Management in Development, World Development Indications, Oxford University Press, 1983.

46. Wyatt, Alan, Wind Energy Consultant, "Trip Report to Morocco", Period covered October 22- November 23, 1983.

47. Wyatt, Alan, "Wind Energy Pilot Project", Ain Tolba Dar El Hamra, Commure de Naima, Oujda Province, 1983.

48. Wyatt, Alan, "Wind Energy Pilot Project": PK8; Oujda; Morocco. 1983.