IRRIGATION AND RURAL CHANGE IN THE SEMI-ARID SERTÃO OF NORTHEAST BRAZIL

by

Ana Maria de Souza Mello Bicalho

Thesis Submitted for the Degree of Doctor of Philosophy

Bedford College, University of London

July, 1985

A B S T R A C T

This thesis is an in-depth case study in Rural Geography based on primary data collected in the semi-arid Sertão of Northeast Brazil. The research analyses the impact of the introduction of capitalized irrigation agriculture into an area of traditional dry farming. The resultant social and economic change is evaluated with respect to the resolution of long-standing regional problems of drought, unemployment, poverty and rural exodus.

Two types of irrigation systems are compared according to the kind of development strategy involved with each. Private-sector irrigation is based on labour-intensive and intermediate technology and represents a model of development from below at the periphery. Capital-intensive farming methods are utilized in public-sector irrigation in function of the centre-down and urban-industrial biased policies pursued in national and regional economic planning. The study thus addresses a number of questions concerning urban versus rural bias, regional dependency and appropriate technology.

Irrigation is found to overcome the environmental and socio-economic problems of the Sertão in a satisfactory way while dry farming does not. Private-sector irrigation does this better than public-sector irrigation. This occurs because flexibility in the production schemes employed in the private sector allows a larger number of farmers to adopt irrigation, more full-time jobs to be created, higher income to be earned by both farmers and workers and greater upward social mobility to take place. The use of capital-intensive technology on government projects severely limits the areas

where public-sector irrigation can be practised. Furthermore, large amounts of scarce capital are spent on an insignificant number of Sertanejo farmers whose cropping activities are only profitable when highly subsidized. In sum, private-sector irrigation better contributes to lessening the problems of the Sertão and to reducing regional and sectorial imbalance and dependency.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ABBREVIATIONS

ANCAR - Associação Nacional de Crédito Agrícola Rural

CHESF - Companhia Hidroelétrica do São Francisco

CODEVASF - Companhia de Desenvolvimento do Vale do São Francisco

CVSF - Comissão do Vale do São Francisco

DNOCS - Departamento Nacional de Obras Contra as Secas

DNAEE - Departamento Nacional de Águas e Energia Elétrica

EMATER - Empresa de Assistência Técnica Rural

EMBRAPA - Empresa Brasileira de Pesquisa Agrícola

GEIDA - Grupo Executivo de Irrigação para o Desenvolvimento Agrícola

GTDN - Grupo de Trabalho do Desenvolvimento do Nordeste

MINTER - Ministério do Interior

IOCS - Inspetoria de Obras Contra as Secas

IFOCS - Inspetoria Federal de Obras Contra as Secas

SUDENE - Superintendência do Desenvolvimento do Nordeste

SUVALE - Superintendência do Vale do São Francisco

ACKNOWLEDGEMENTS

I am most grateful to the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) and the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for grants that enabled me to pursue my doctorate studies at the University of London and to carry out field research in Northeast Brazil.

I want to thank my supervisor Michael J. Eden for reading through the various drafts of the thesis and for offering many useful suggestions & criticism which improved the thesis.

I am also indebted to the farmers and workers of the study area for the help they gave me in trying to understand the difficulties involved in their way of life. Of these, I would like to especially thank Nelson & Célia Alves and Tiburtino & Fâtima Carvalho of Belém do São Francisco; Laudimiro & Nicanor Veras of Chorrochó; and Niça & Sinô Miranda and João & Doza Miranda of Parnimirim.

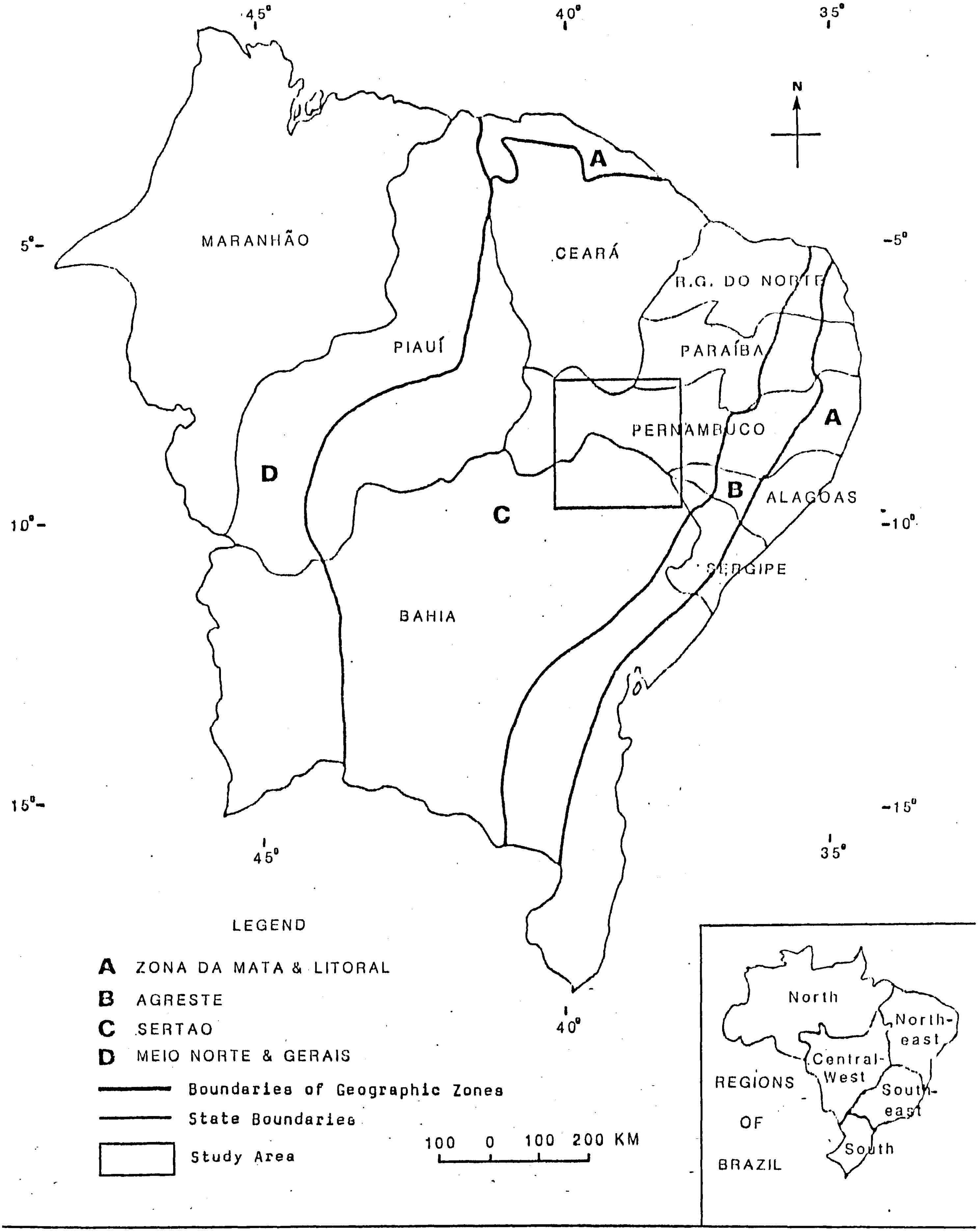
Carlos Caldas Lins of the Superintendência do Desenvolvimento do Nordeste in Recife gave me invaluable assistance in obtaining bibliographic and environmental information as well as help in contacting various specialists of the region. The personnel of the various offices and projects of CODEVASF and DNOCS also were most helpful in the insights and information which they provided.

I also want to thank Ana Luiza Coelho Neto who analysed soil samples for texture and Bendix J.C. Lima who provided information for soil interpretation. Pamela Fyfe was of great help in her proof reading of the text and Miguel Farah Neto helped produce a number of figures. Finally, I am most indebted to Scott W. Hoefle who helped with the field research, offered suggestions and criticism, and did a first-rate job of typing the thesis.

1. IRRIGATION AND THE PROBLEMS OF THE BRAZILIAN SEMI-ARID ZONE

The Brazilian Semi-Arid Zone, known as the Sertão, is located in the interior of Northeast Brazil (Figure 1). Like the rest of the Northeast, the Sertão is underdeveloped and suffers grave problems of unemployment, underemployment, large-scale emigration and sharp social disparities. Many of these problems are felt very acutely in the Sertão because of the semi-arid environment where drought strikes on an average of every four years.

Drought has long been considered to be at the heart of the regional problems. In consequence, development policy has always been aimed at alleviating the impact of drought. From the end of the last century until the 1960s, long-term policy was basically one of creating large reservoirs in order to ensure a reliable water supply. Short-term action in times of drought was - and still is - the employment of poor farmers in temporary public work projects in an attempt to keep the rural population in the region when harvests failed. Unfortunately, merely supplying water and temporary employment have not been enough to solve the problems of the Sertão. In the late 1960s, the planning agencies embarked upon a more ambitious programme of developing irrigation in an attempt to restructure the rural economy. Only by doing this was it thought that the drought problem could be attacked at its roots (DNOCS, 1976; Hall, 1978; MINTER, 1973; Souza, 1979).



After: Andrade (1973) and Melo (1978).

Figure 1. Geographic and Political Divisions of Northeast Brazil.

RESEARCH OBJECTIVES

The objective of this work is to evaluate the introduction of irrigation into the Semi-Arid Zone. This involves asking two fundamental questions. Is the adoption of irrigation agriculture the best way to bring about positive rural transformationin the Sertão? If so, which type of irrigation will give the best results in the long-term?

Inherent in the first question is a comparison between irrigation and dry farming as practised in the Sertão and the relative possibilities for improving both. Since 1968, the government has opted for specialized irrigation. In the last decade grave reservations about the environmental and social implications of the practice of irrigation in the Semi-Arid Zone have been expressed and instead a course of action in which the traditional activities are modernized and made more resilient to drought has been suggested (Coelho, 1974; Hall,1978).

Unfortunately, these reservations are based on the criticism of public-sector irrigation in an isolated way. The entire setting of government projects is seldom considered, even when neighbouring private-sector farms utilize irrigation. Private-sector irrigation is rarely considered nor is the possibility of associating irrigation with improved dry farming. These latter considerations are crucial for evaluating the role of irrigation in solving the regional problems and they are included in the comparison of irrigation to dry farming made here.

The second question involves considering which type of irrigation technology system is best adapted to the environmental and socio-economic conditions of the Sertão. Most private-sector irrigation farmers utilize an intermediate technology, where both capital and labour are important inputs, while public-sector irrigation is invariably capital-intensive. So another basic point of evaluation is to determine which of these offers the best possibility of wider diffusion throughout the zone and for bringing about desirable change.

The two types of irrigation systems identified in the Sertão - private-sector and public-sector - also represent different kinds of development strategy. The objectives of the two differ fundamentally as do the beneficiaries of the changes provoked by the introduction of each. The type of irrigation practised in the private-sector represents a model of development from below while the capital-intensive farming methods utilized in the public sector are a response to the centre-down policies pursued by government development agencies.

Public-sector irrigation is part and parcel of a national economic policy which is heavily biased in favour of the urban-industrial and export farming sectors, while private-sector irrigation has, for the most part, been devised by local farmers with their own interests in mind. This study is thus a contribution to current debates over whether development strategy should emphasize the centre or the periphery, should proceed from the top down or from below and should have an urban-industrial bias or rural-agricultural bias. Furthermore, it is hoped that these issues are addressed in such a way as to provide new insight for regional planning in the Northeast.

In a wider context, the research seeks to analyse the more general process of rural change by examining the impact of a new productive system, in this case irrigation, in a region of peasant agriculture. Also, by providing an in-depth study in agricultural geography, based on primary data, a contribution can be made towards the formulation of more accurate theories and models in this field. The lack of detailed empirical information, particularly in the developing countries, has been stressed as having limited the formulation of sound theories and concepts in rural studies (Morgan & Munton, 1971).

A final research objective concerns the use of arid lands. Until recently, studies of semi-arid and arid environments have mainly emphasized the negative aspects of such regions and have not focussed on how they can be developed. The majority of these regions are underdeveloped and occupy one-third of the earth's land surface. Their potential needs to be exploited more intensively in order to feed a hungry world and to diminish social disparities that threaten human well-being (Dregne, 1970). Hence, a detailed study of man's struggle to cope with the environment of the Sertão of Northeast Brazil and the role played by irrigation in this effort, can contribute to our general knowledge of these environments and their development.

Based on these considerations this work will prove the following propositions:

1. Irrigation better withstands drought than does traditional dry farming, creates greater job opportunity, raises rural income, generates farm capital and reduces rural exodus. However, irrigation can only be practised on a large scale in restricted areas of the Sertão and on a minority of the land.

2. The inflexible use of capital-intensive technology and closed, centralized farm administration in public-sector irrigation is the result of the top-down development strategy pursued. By utilizing different types of irrigation technology, ranging from labour-intensive to capital-intensive, and various forms of land tenure and labour relations, private-sector irrigation is more easily adapted to

differing local socio-economic conditions and so diffuses more readily.

3. Public-sector irrigation benefits a minority of farmers, few jobs are created, social polarization is widened and rural exodus is not curbed. Numerous jobs are created in private-sector irrigation, immigration replaces rural exodus, high income is earned by a large number of farmers and workers and a process of capital formation takes place, thus fuelling the expansion of irrigation.

GOVERNMENT POLICY IN BRAZILIAN AGRICULTURE

The viability of irrigation as a farming system in the Sertão must be evaluated at all levels and not just in local terms. National and regional development policy has a profound influence on farming in Brazil. Opportunities are created, and limits are imposed on the kind of crop and the type of farming methods which can be profitably exploited.

As Brookfield (1975, 1979) and Lipton (1977, 1982, 1984) describe for most developing countries and Yudelman & Howard (1970) for many Latin American economies, the agricultural sector in Brazil is strictly controlled and manipulated by the federal government. Brazilian farm policy is subordinated to an overall development plan which lays greater emphasis on the expansion of industry. Agriculture must contribute to industrial growth. The main function of farming is to generate export earnings in order to finance key capital imports for the manufacturing sector. Also as the growth of industry has led to rapid urbanization and the concentration of population in large cities, another important function of Brazilian agriculture is to supply the large urban domestic market with cheap foodstuffs. Low priced staples are crucial to government policy so that the cost of industrial labour can remain low and the export competitiveness of manufactured goods can be maintained (Aguiar, 1981; Albuquerque, 1981; Goodman & Redclift, 1981; Oliveira, 1975; Silva, 1977).

Since the 1930s the State has increasingly intervened into the marketing and pricing of produce in Brazilian agriculture with policies to stimulate export activities as well as to hold down the price of staples for the urban market (Albuquerque, 1981; Goodman & Redclift, 1981; Oliveira, 1975, 1977). Export crops and non-basic food crops receive the lion's share of bank credits and seldom experience price control. The price of such crops as cocoa, coffee, oranges, soya beans, vegetables and certain luxury fruits are what the international and national market will bear. Hence, they are highly commercial and they attract most farm investment. Stock-raising is another rural activity that receives considerable stimulus because it is basic to the exportation of processed meat, is very important for the urban market and involves large ranchers who possess political influence.

As Lipton (1977) notes for most Third World countries, basic staples for the Brazilian internal market suffer the opposite effects of policies which he terms 'price twisting'. A number of direct and indirect methods of price control are employed by the government in policies which impoverish the staple farmers. Government support prices for staples are usually set at unrealistically low levels. Retail food prices in the large cities are controlled in such a way as to limit rises in wholesale prices which, in turn, result in low prices to the producers.

Government policy notwithstanding, staple production has not been eliminated because most Brazilian food cropping is undertaken by peasant smallholders (Carvalho, 1978; Silva, 1977). These farmers are more interested in a steady and reliable income than in explicit calculations of profits. They are able to plant low profit crops because their production costs are lower than those of larger land-owners. This is achieved through the use of labour-intensive methods based on the ample use of non-salaried family workers. Thus, these producers exploit staples both for subsistence as well as for the market.

However, when planners set prices too low, not only do large specialized farmers lose interest in planting low priced crops but peasant farmers do so too. The latter simply restrict the production of the low priced staple in question to that of their own subsistence needs and plant more of other crops for the market. When this occurs on a large scale, as it did with beans, maize and rice in the late 1970s and early 1980s, the government is forced to import the scarce items and in so doing defeats the development policy of import substitution. Instead of agriculture earning hard currency through exportation, money goes out of the country to pay for food imports.

When such shortages occur, one way of stimulating the domestic production of scarce foodstuffs is to finance their production with subsidized bank loans and to allow a certain increase in produce prices. Brazilian agriculture is highly responsive to these stimuli and from one year to the next, staple shortages can disappear. When the crisis is over, the government reverts to the former policy of maintaining a low price for the problematic crop. Once again, over a period of a few years, farmers gradually reduce planting the staple as the price falls.

In the last two years this situation has been complicated by the external debt crisis and by the demands of the International Monetary Fund for an end to subsidies. As a result the government has been forced to cut back drastically on subsidized credit for agriculture.

The Brazilian rural economy presently stands at a crossroads. Cheap credit is no longer available and this has profound repercussions for the kind of irrigation technology which can be used for each type of crop. Furthermore, the long-term perspectives for the diffusion of irrigation are highly dependent on the state of the national economy. The economy has been depressed since the mid-1970s and the boom years of rapid growth are over. This means that less public funds are available for rural development projects and falling income limits the growth of consumer markets. Within this context, government policy toward irrigation needs to be reconsidered. Thus the time is right for a detailed analysis of the irrigation systems in the Sertão in order to determine which best fits the present circumstances of the country.

PRIVATE AND PUBLIC IRRIGATION IN THE NORTHEAST

Brazilian government policy is formulated according to the needs of the economy of the industrial Southeast and South and, as Fox (1979) and Goodman & Redclift (1981) demonstrate, both the industry and export agriculture of these two regions receive the greater part of private and public investment. In a classic case of unequal centre-periphery relationship and urban-industrial bias, the Northeast is insignificant in this general policy and so receives what resources are left over. The region is only considered when its problems spill over into the southern half of the country and threaten to act as a brake on development there.

The outflux of poor Northeasterners to the industrial cities of the Southeast in particular is an acute problem as they add to the mass of unemployed workers there. The low income earned in the Northeast is also seen as an economic barrier to the expansion of southern industries. Lastly, the social unrest generated by the depressed situation in the Northeast is viewed as a serious menace to the political stability of the country (Albuquerque, 1981; Forman, 1975; Hall, 1978; MINTER, 1973).

In an effort to control and improve the situation and despite the bias to developing the industrial heartland, the federal government has been forced gradually to take increasingly more ambitious measures aimed at the Northeast. Since the 1950s, the Northeast has been receiving greater aid and assistance which is channelled through planning agencies that were set up in the region. The most important ones are the Banco do Nordeste do Brasil and the Superintendência de Desenvolvimento do Nordeste (SUDENE). Two other agencies with more specific functions and areas of action are the Departamento Nacional de Obras Contra as Secas (DNOCS) and the Companhia de Desenvolvimento do Vale do São Francisco (CODEVASF). These two agencies are responsible for promoting irrigation in the region.

Government development projects in the Northeast are mainly concentrated in the state capitals and in industry, which repeats at the regional level the urban-industrial bias of Brazilian development. However, a substantial amount of aid goes to the semi-arid hinterlands due to the problems caused there by drought. There are a number of programmes aimed at developing the Sertão, of which irrigation has assumed the greatest importance. Not only is irrigation expected to resolve the problem of crop failure caused by drought, but in addition it is thought that irrigation can bring about rapid rural development through the modernization of agricultural technology, the increase of commercially orientated production and the raising of farm incomes. With this the government hopes to reduce emigration from the Semi-Arid Zone as well as to integrate the area into the national economy. In short, the zone would cease to be a drain on scarce funds and instead it would contribute to national development (DNOCS, 1976; Hall, 1978; MINTER, 1973).

From the 1930s to the late 1960s government policy for promoting irrigation focussed on various schemes intended to demonstrate and help finance the adoption of irrigation methods by local farmers of the private sector. These efforts are thought to have been a failure and blame is usually pinned on the backwardness of latifundia ranchers (Hall, 1978; MINTER, 1973; SUDENE, 1974, 1979). In fact, the thesis here is that considerable development of private-sector irrigation has occurred but it only came about when the basic rural infrastructure and transport facilities were sufficiently improved to allow this to happen.

As Hunter (1969) shows to be common elsewhere in the less industrialized world, governments often become impatient with what is considered to be slow progress in rural development and are tempted to intervene directly. This occurred in the Sertão and the government response to its own impatience was the creation of public irrigation projects. The projects are imposed from the national and regional level and are established in a relatively short period of time. They are, therefore, an example of accelerated development from the top down and from centre to the periphery. The government justifies this course of action as being the quickest way to change the local agricultural system which is thought to be resistant to change. To guarantee the success of the projects in the shortest period possible they are implanted and administered directly by technicians from DNOCS and CODEVASF.

On public irrigation projects, the land is usually divided into small plots which are turned over to selected rural families. However, apart from the work in the fields project farmers have little power of decision. All stages of farming are controlled by the project administration from when to plant which crop during the year up to the final marketing of produce. Farmers have to follow the rules of the project and if they do not, they are asked to leave.

In terms of technology, all projects are based on a set template of capital-intensive irrigation, in the belief that modernization, efficiency and large-scale production can only be achieved in a very sophisticated system. As the basic infrastructure of canals, pumps and electricity is very expensive, far beyond the means of most Sertanejo farmers, the government has had to heavily subsidize the projects. Furthermore, the administrative personnel is paid by public funds. Farmers cover operating expenses, such as seed, fertilizers, pesticides, water and contracted labour.

In recent years both CODEVASF and DNOCS have started to implement a private-sector joint venture scheme in which the agencies provide land and the irrigation infrastructure. Large capitalist farmers and agribusinesses rent this land with the option to buy it after five years. The CODEVASF programme was already in its first phases of operation so that it could be studied in the field. It will be shown to suffer all the drawbacks of the public-sector system and to have few of the positive aspects found in the family farmer programme.

Besides the government sponsored irrigation projects, an expanding private irrigation sector exists which has been dynamic in producing change in certain areas, such as on the São Francisco and Jaguaribe Rivers. However, there is a gap in the literature concerning private-sector irrigation of the Sertão. Practically nothing on the subject has been done since the 1950s when the Banco do Nordeste (1957) and Pierson (1972) did research in the São Francisco area.

This is particularly unfortunate as it is the private-sector irrigation which is diffusing most rapidly. Local farmers have developed a very practical, efficient and profitable type of irrigation technology. Furthermore, as government funds will never be sufficient for directly implanting irrigation throughout the whole Sertão, this task will ultimately fall to the private sector. So it is imperative to understand how private-sector irrigation farming has evolved in order better to coordinate public action to farmer needs.

Private-sector irrigation is encountered on farms of all sizes and presents a range of technology types, from labour-intensive to capital-intensive. The choice of what to plant and how; which inputs to utilize; to whom, when and where to sell produce and all other farm activities are in the hands of the farmers. Farmers make decisions based upon their ability to invest in irrigation and according to the market opportunities of the moment.

Over the last thirty years cropping methods utilized on most private-sector irrigation farms have evolved from a labour-intensive type to an intermediate type. Due to limitations in access to technical assistance and to bank loans much of this change has been based on individual experimentation by farmers and financed through the re-investment of profits. This is a classic example of development from below and at the periphery.

Private and public irrigation, therefore, represent diametrically opposed models of rural transformation. In order to evaluate which best promotes positive change, both private-sector and public-sector irrigation will be analyzed in a specific area of the Sertão where the two systems have existed side-by-side for a period of about three decades. The two will be compared in a systematic way to one another as well as to dry farming in respect to the diffusion of more intensive farm technologies, the impact on the environment, the socio-economic viability within the regional and national context and the social implications of such rural change.

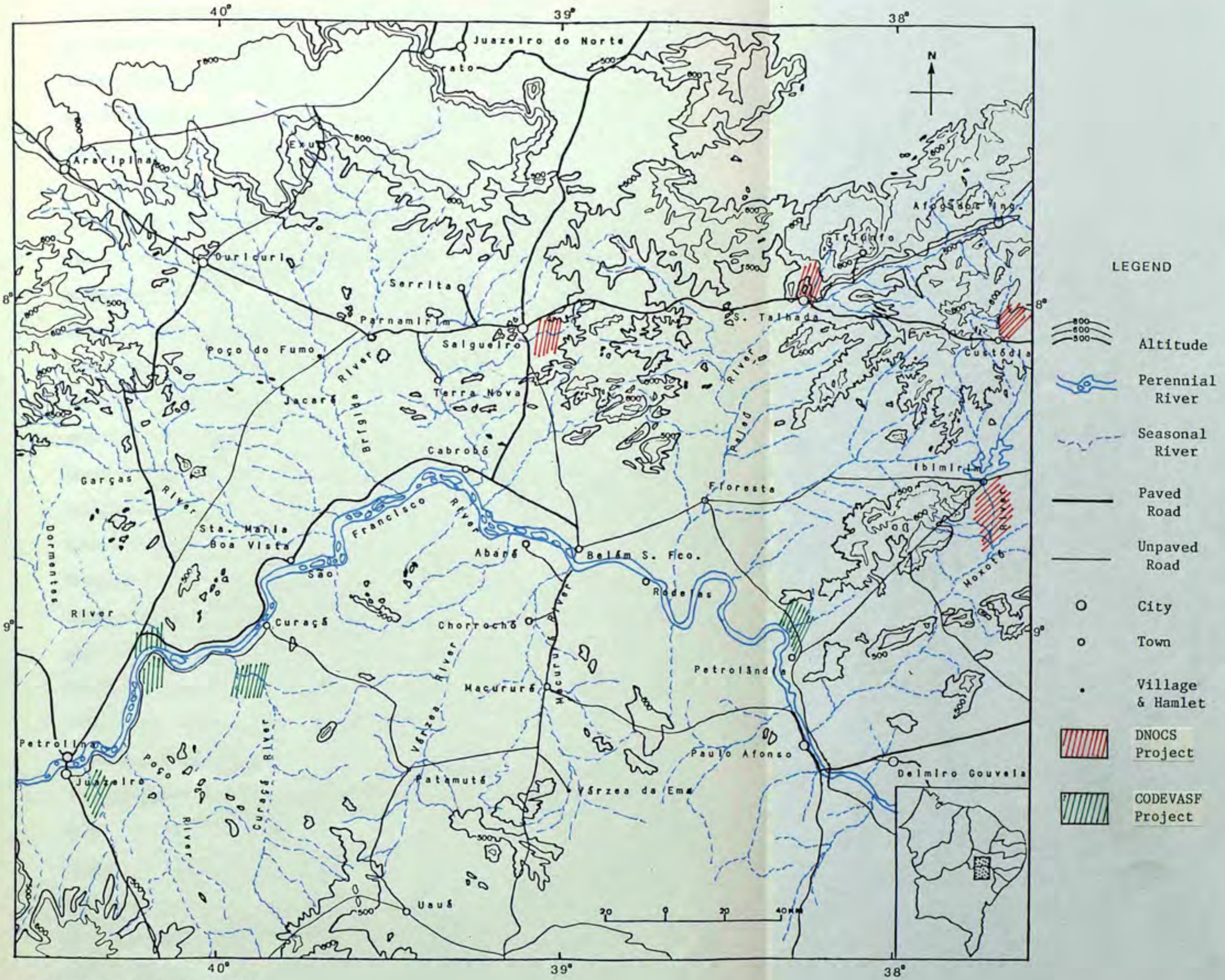
THE FIELD RESEARCH

The period researched was from 1950 to 1981 when it can be said that irrigation really started to diffuse in the Sertão. Most statistical and other secondary information for irrigation, though, dates from post-1960 and reference to times prior to this can only be made when information is available.

To fulfil the objectives and to prove the general propositions of the research, the lower-middle São Francisco Valley was studied in detail. A total of two years of field research in the Sertão was undertaken in two separate periods. The first was from 1977 to 1979 and the second was in 1981. Fieldwork was conducted in the counties of: Belém do São Francisco, Cabrobó, Petrolina, Salgueiro and Santa Maria da Boa Vista in Pernambuco State and in Abaré, Chorrochó, Curaçá, Juazeiro and Rodelas counties in Bahia State (Figure 2).

Both private-sector and public-sector irrigation are found together in this area alongside traditional dry farming. Ecological conditions for both irrigation and dry farming vary from being favourable to being the exact opposite. Demographic conditions as well as rural and urban infrastructure also differ considerably so that the area is quite representative of the variation found in the Sertão as a whole.

For the analysis of dry farming the study area is divided into a northern part and a southern part. Environmental conditions in the North are favourable for the practice of dry farming while in the South they are not. In terms of irrigation, the study area is divided into the area along the São Francisco River and that of the tributaries. Conditions along the main stream are good for the practice of irrigation while those on the tributaries are less favourable.



After: Fundação IBGE (1972).

Figure 2. The Study Area.

A total of 136 private-sector farms were visited in the counties researched and questionnaires were applied to 118 farm owners, 18 tenant farmers and 54 workers. Of these, 54 were irrigation farmers, 18 irrigation tenant farmers, 26 irrigation workers, 64 dry farming landholders and 28 dry farming workers (Appendix 1).

The public-sector irrigation projects studied were the Bebedouro and Tourão projects under the administration of CODEVASF as well as the DNOCS projects of Boa Vista, Custódia and Moxotó. The large Bebedouro project (near Petrolina) occupies 5097 hectares and in 1981 had 105 small project farmers and two large tenant farmers. At this time the large Tourão project (near Juazeiro) was still in the installation phase and consisted of an agribusiness sugarcane complex covering 6083 hectares and employing 1473 workers. Boa Vista (near Salgueiro) is a small project with 26 family farmers and occupies 280 hectares. There are 47 small farmers on the medium-sized Custódia project (near Custódia) which possesses an area of 1804 hectares. The new Moxotó project (near Ibimirim) is one of DNOCS's largest, covering an overall area of 4968 hectares with 426 plots planned and with 121 small farmers installed in 1981. Data were compiled from project and headquarters archives, administrators and technicians were interviewed, and questionnaires were used on the Bebedouro and the Boa Vista projects when talking to project farmers.

Parallel to the collection of primary data in the main research area, a survey was made of other areas in the Semi-Arid Zone in the states of Bahia, Ceará, Paraíba and Pernambuco. Rural extension agents and local informants were interviewed in 18 counties in order to learn about the local practice of irrigation and dry farming. This general information proved to be quite helpful for generalizing about farming in the Sertão.

Secondary data were obtained in government agencies located in Fortaleza, Recife and Petrolina. The agencies in Recife were: the general headquarters of SUDENE, the II Regional Department of DNOCS, the VI District Office of DNAEE (Departamento Nacional de Águas e Energia Elétrica), the state office of CPRH (Companhia Pernambucana de Controle dos Recursos Hídricos) and the headquarters of the Projeto Asa Branca. The general headquarters of DNOCS was visited in Fortaleza and in Petrolina work was done in the IV Regional Office of CODEVASF.

Finally, rural and demographic information was collected in Rio de Janeiro from the Brazilian Census and general economic statistics from the Fundação Getúlio Vargas. These data complement those collected in the field and those obtained from planning agencies in the Northeast, thus allowing for greater generalization from the study area to the regional level.

2. IRRIGATION AND RURAL CHANGE

The introduction of irrigation into the Sertão should be seen in the light of government efforts to promote rural change in the Less Industrialized Countries as well as in the context of the general transformations that are not directly linked to government action in these nations. There are three ideal types of government intervention: direct, indirect and *laissez-faire*. Gordon (1972) has termed these, respectively, the radical-socialist, liberal and conservative models of government action. Over the years each model has had advocates in the various debates concerning the place of agriculture in development.

In the direct approach the government assumes control of the means of production and, in the case of agriculture, it sets up state farms whose operation follows the dictates of overall economic policy. In the indirect approach government concentrates on making general infrastructural improvements and relies on pricing, credit and rural extension policy to promote change on private farms. The *laissez-faire* approach is that of letting the market work its course with minimal government intervention.

Through the centuries, the approach of the Brazilian government toward the plight of the Sertão has gradually shifted from the *laissez-faire* model to that of indirect and direct intervention. Today the two types of irrigation encountered in the Sertão - private-sector and public-sector - are respectively examples of the indirect and direct approaches. The merits and drawbacks of each will be the central theme of this work.

In this chapter, the place of agriculture in development theory is discussed in the first section. Then, a model of worldwide irrigation technology types is postulated. The types identified - capital-intensive, intermediate and labour-intensive irrigation technologies - are shown to represent competing views of the role of agriculture in development. The diffusion of each type of irrigation is demonstrated to involve a bundle of different environmental and socio-economic consequences, i.e. each is a different productive system much in the way that Marxists talk of modes of production. Each system is adapted to specific situations and not well adapted to others.

Throughout the thesis it will be argued that capital-intensive irrigation is not appropriate for the present situation of the Sertão. Intermediate technology is shown to be better adapted for the planting of some crops in the Semi-Arid Zone while labour-intensive irrigation is the best technological choice for others. The combination of intermediate and labour-intensive technology is demonstrated to best promote positive rural transformation by lessening the burden on government finances, increasing the overall contribution of agriculture to industrial development, relieving population pressure, stemming rural exodus, increasing employment opportunity, permitting more equitable distribution and lessening social disparity.

DEVELOPMENT AND AGRICULTURE

Since World War II, and the great political and economic changes that were ushered in, a different view of change and disparity between nations and regions has arisen. Colonial perspectives of slow evolutionary change or of innate racial and climatic differences have been replaced by efforts to try to reduce the disparities between the industrialized countries and the rest of the world. This was undertaken not merely out of charity but also out of economic and political self-interest (Brookfield, 1975; Kay, 1975; Kitching, 1982;

Valenzuela & Valenzuela, 1981). The problem perceived and taken up still defies solution today, more than thirty years later (Hirschman, 1979). Indeed, more recent theories point to the opposite having occurred over the last two decades. Disparity has become greater between the developed and developing countries and between regions within developing countries (Arnon, 1981; Brookfield, 1975, 1979; Griffin, 1981; Harvey et al., 1979, Lipton, 1977; Pearse, 1980; Smith, 1979).

The Modernization Approach

In the 1950s and 1960s the underdeveloped countries were viewed as basically agrarian societies and the problem was seen to be that of modernizing them, i.e. transforming their economic and social structures to that of an industrial society. Otherwise, these nations would never escape the vicious circle of poverty, overpopulation, famine and general misery associated with a peasant way of life. To industrialize was to acquire political and economic power, material plenty and social well being. This was the point of view of the Western specialists concerned with the subject, the local elite and finally, after some time, the general population as the ideology was disseminated by the mass media (Brookfield, 1975; Cardoso & Faletto, 1979) Needless to say all these were painting a much too rosy picture of the existing industrial societies, which were taken as the final goal of development, as well as underestimating the price required to obtain it.

Of the various debates what is of interest here is the fact that industry was given priority by nearly everyone involved and agriculture was relegated to a place of secondary importance. This was unfortunate as agriculture was the base of these societies and hence its transformation would be central for laying the foundations of industrial development. Instead, the relationship of the rural sector with the rest of the economy was given most of the attention rather than problems within the sector. The problem was seen to be mainly one of transferring so-called 'underutilized' resources from farming, oftentimes with the Soviet experience as a model (Brookfield, 1975, 1979; Chambers, 1983; Goulet, 1983; Lipton, 1977).

a) Dualistic Models

In the various development models of the 1950s and 1960s, little positive was said of the internal structure and functioning of the rural sector of the developing countries other than that modernization, i.e. industrial or capitalized agriculture, was the goal. This commonly meant how the local conditions were to be adapted to this type of farming and not vice versa. With the exception of plantations, the farming sector of the Third World was portrayed as traditional and stagnated and as such it could do little to contribute to the growth of the economy, or worse, it was considered to retard development.

According to this view, the rural zone in the less developed countries suffers numerous problems, such as overpopulation, underemployment, a tradition-bound social structure and above all rural poverty, all of which act as barriers to change. The urban-industrial sector is envisaged as being the opposite of the rural sector. It is characterized as the innovative, modern and prosperous part of the economy in which continous change is observed. Given such features, this is thought to be the sector that can best absorb influences from other modern economies and societies while the 'backward', 'traditional', 'old', 'miserable' or 'static' peasant agricultural sector is resistant to change [Bastide, 1971; Lambert, 1969; Boeke, Higgins, early Myint, Fei & Ranis, Jorgenson (cited in Morgan, 1977)].

b) Balanced and Unbalanced Models

Another dominant theme of the 1950s and 1960s was the discussion of balanced and unbalanced models of development. Here more activist models are encountered where agriculture could theoretically be given an important role in contributing to development. It was not, though, and the best scenario was to put agriculture on par with industry (Brookfield, 1979; Malassis, 1975).

The emphasis given to the urban-industrial sector in the dual models can be thought of as being the basis of the unbalanced growth approach. In the models of Hirschman (1971) and Perroux (cited in Malassis, 1975), the targetted areas and sectors to be stimulated, in order to achieve development more rapidly, are almost always urban heavy industry. Agriculture, on the other hand, is usually slighted because it is not considered to be a sector which can contribute toward rapid development.

The strategy of balanced growth as put forth by Nurkse (1971), Rosenstein-Rodan and Lewis (cited in Malassis, 1975), is one that considers both the industrial and agricultural sectors as being equally important for development. An interdependency is thought to exist between the sectors, with development being ultimately obtained through the gradual transfer of resources from the agricultural sector to the other sectors. This is achieved in such a way that all the sectors of the economy develop at more or less the same pace in order to avoid sectoral imbalance and bottlenecks. While this approach involves less risk than the unbalanced view of large investments concentrated in a few key industries, there is the chance that the surplus may never arise because it is simply consumed by a larger rural population or siphoned off to benefit other regions or countries in a colonial or neo-colonial pattern (Geertz, 1963; Malassis, 1975).

On the whole, the balanced versus unbalanced development debate has remained very theoretical. Economists argue about the merits of ideal types and do not contribute much to development in the real world (Morgan, 1977). In practice, transferring resources from agriculture to other sectors has proved to be dangerous to the economy and to the social fabric when too much is demanded of the rural zone and when the rapid extraction of resources proves detrimental to the functioning of the existing farm system.

The Critics of Modernization

In the late 1960s it became apparent that simply encouraging industry and neglecting the countryside was producing the opposite effect to that desired in both urban and rural zones. Three schools of thought arose in reaction to modernization theory: dependency theory, urban-industrial bias theory and appropriate/intermediate technology theory. The first line of thought was a resurgence of Marxist theory, while the second was more a liberal critique of the initial results of development. The third position was both critical of capital-intensive industry and agriculture and disillusioned with the overly theoretical nature of much of the debate in development studies.

a) Dependency

Advocates of dependency theory, such as Baran (1968), Frank (1969, 1970), Santos (1983) and Wallerstein (1981), criticize the modernization approach for being ethnocentric and pointed out that a simple repetition of the Western experience was impossible. The developing countries were stuck in a peripheral status within the world economic system and it would be extremely difficult for them to advance beyond the status of primary producers. Unless protective tariff walls were erected local industry would never develop. This point of view was, in turn, challenged by Warren, Lall and Leys, among others, who pointed to the relative success of some developing countries, such as Brazil, Korea, Singapore and Taiwan, as proof that the alternative is not merely underdevelopment or revolution. This may be true but most other developing countries face even more obstacles which have arisen in the last decade, so that while various routes out of dependency are possible, the road is a difficult one (Bienefeld, 1980; Godfrey, 1980; Muñoz, 1981).

b) Urban-Industrial Bias

At about the same time that dependency theory and world system analysis were at their height, in the 1970s, another critical point of view arose which took the strong urban-rural disparities of the developing countries as its point of departure. Brookfield (1975, 1979), Chambers (1983), Lipton (1977, 1982, 1984), Mamalakis, Mitra and Bates (cited in Harris & Moore, 1984) try to explain many of the barriers to development and the widening disparities that have been noted as being the result of the domination of the urban-industrial sector over the rural-agricultural sector. In the developing countries, government policy is one which encourages the growth of industry, commerce and services in the urban zone at the expense of the countryside, often through the discriminatory pricing of rural products.

This point of view has been criticized by Byres (1974, 1979) Corbridge (1982), Harris & Moore (1984), Moore (1984) and Redclift

(1984). These authors hold that the urban-rural divide is not so socially and economically clear cut, cash cropping is overlooked, intra-sectoral class relations are ignored, geographical factors are not taken into account and international dependency relationships are more important than sectoral clash for explaining specific characteristics of less industrialized economies. While many of these arguments may be correct with respect to Lipton and some other of the urban-bias authors, they are not correct for Brookfield's work and, in fact, these critics do not even treat him at all. Moreover, as most of the critics themselves admit, despite some flaws, the basic argument of this school is valid. Agriculture has been slighted in development policy and the urban-industrial sector overly favoured.

c) Appropriate/Intermediate Technology

If most development debate is overly theoretical or too general, the various proponents of appropriate or intermediate technology are quite concrete in their suggestions at to how to promote change in the less industrialized world. The work of Dunn (1978), Evans & Adler (1979), Schumacher (1973) and Stern (1979) for example, are mainly collections of the various alternatives presently available in Third World technology which might be adopted in other countries with similar local conditions. With the urban-bias school of thought they share a general distaste for the waste and inequality involved in most large industrialization projects but they offer more concrete suggestions as to what needs to be done.

A number of drawbacks have been pointed out concerning this line of thought. Byres (1974, 1979) and Sutcliffe (1984) go so far as to label both intermediate technology and rural-bias strategies in general as pipe dreams and so much romanticizing of the rural way of life. These authors are correct that the rise of a manufacturing sector is necessary for developing countries. The same argument against balanced development can be made of intermediate technology strategies, i.e. a surplus for industrialization may never become available due to the occurrence of rural 'involution'. Population growth in general and demographic pressure on farm size in particular mean that an industrialization policy is also necessary in order to employ the surplus rural population. As Corbridge (1982) observes, just as industrial policy cannot ignore the countryside, so rural policy must be coordinated with that for the cities.

In all fairness to this school of thought it should be pointed out that advocates of appropriate technology are not opposed to development per se but look for ways to promote change with the least amount of harmful side affects. They treat light manufacturing and crafts as much as they do farming, and they search for ways to employ the largest number of workers with the capital available.

Where all three critical schools of modernization are in agreement concerns the condemnation of industrialization policies which are mainly based on destroying the peasantry and impoverishing the rural zone. When applied to agrarian societies, be they capitalist or socialist, the consequences have been appalling, and as a result the cities have been overwhelmed by immigrants fleeing the countryside (Brookfield, 1975, 1979; Chambers, 1983; Lipton, 1977, 1984; Malassis, 1975; Roberts, 1978). Not only theorists but politicians and planners have become alarmed as well. Schumacher (1973) is no longer alone in his concern for creating jobs in the countryside rather than provoking the uncontrolled transfer of rural population to the cities.

Nevertheless, most planners still only pay lip service to ideas of appropriate technology and to what Pearse (1980) calls 'peasant-based strategies' of rural transformation. Development policies still encourage the practice of large-scale, capital-intensive forms of agriculture at a time when rising energy costs, unserviceable foreign debts and the growing restlessness of the urban and rural poor have dimmed the prospects for such systems. Fashionable terms are merely applied to the same projects in order to obtain international loans instead of rethinking how they should be done.

The line of analysis adopted here will be one that combines various points from all three of the schools which criticize the modernization view of development. For the region being studied, what is the best way out of the present situation of dependency on the economic centres of the Northeast and Southeast of Brazil? Which is the most appropriate rural technology that can bring this about? How can farmers free themselves from the dictates of urban orientated planners?

Within these general considerations, irrigation as an intensive form of farming takes on importance. It has been a traditional way of increasing production in many parts of the world. A variety of irrigation technologies exist which range from very labour-intensive types to very capital-intensive ones, each of which is adapted to varying local environmental and socio-economic circumstances. The activity is also well adapted to gradually accepting various kinds of technical innovations. Finally, being an intensive form of farming that is also amenable to absorbing large quantities of labour, irrigation can help resolve the pressing problems of declining farm size, underemployment, low rural income and sectoral disparity in the less developed world.

ALTERNATIVES IN IRRIGATION AGRICULTURE

Past, Present and Future

Irrigation is distinguished from other farming systems by its control of the water used for cultivation. Water control gives the system specific characteristics concerning technology and social organization. Historically, the complex water control and distribution systems developed for irrigation stimulated or at least accompanied, the rise of the first state political organizations in the Near East, India, China and in the Americas (Adams, 1966; Bailey, 1981; Steward, 1955; White, 1959; Wittfogel, 1959; Wolf, 1982). However, simpler forms of irrigation existed in the past - and still exist today - which do not require such large-scale or collective forms of organization and are adapted to the practice of irrigation on small production units (Heathcote, 1981; Kelly, 1983; Sahlins, 1966).

Although irrigation has been quite important in regions with insufficient or over-concentrated precipitation for reliable agriculture it can be found almost everywhere, in humid and dry lands alike. In parts of Europe and North America, where rainfall is distributed more evenly through the year, irrigation provides the means for supplementing the supply of water in order to regularize the watering of crops. However, the importance of irrigation is far greater in zones of concentrated and sparse rainfall. In Monsoon Asia and Mediterranean regions irrigation enables a harvest to be made during the intensely dry season. In arid and semi-arid areas irrigation is often crucial for creating the conditions necessary for any regular practice of agriculture in an hostile environment (Cantor, 1967; Hodder, 1973; Ruthenberg, 1980).

As irrigation enables the intensification of rural production and the utilization of land unsuitable for rain-fed agriculture, this farming system has been very important in the past and still is in many parts of the world. Moreover, its importance will grow in the near future by contributing to the production of food and organic raw materials throughout a large part of the world. This was pointed out in the international conference on Arid Lands in a Changing World, sponsored by the American Association for the Advancement of Science and UNESCO in 1969. "There is a fear that the food resources of the world are inadequate for the population that is foreseen in the 21st Century, no matter how well they are developed and utilized. The unanswered question is whether mankind will permit the population to increase indefinitely at the current rapid rate. Certainly, if this happens, the day of reckoning cannot be delayed significantly unless intensive irrigation agriculture is practiced in the overpopulated regions" (Dregne, 1970: 9). This author expects that, with the diffusion of irrigation, the arid zones of the world will suffer radical transformation. Regions that were considered to be inhospitable, remote and unimportant, and which to date have been overlooked, will show great potential for development.

Irrigation originated in the arid and semi-arid regions of Asia, Africa and the Americas between 3000 and 2000 B.C. (Adams, 1966). The structures and technology in general were of a labour-intensive nature based on the use of human, animal and natural forces. Irrigation technology did not suffer dramatic modification until the end of the last century when more capital-intensive forms arose. Before this time, irrigation had spread spatially by incorporating new areas of previously less intense farming systems in a way which Geertz (1963) terms 'involution'. The new areas were exploited more intensely but the irrigation system itself did not change significantly.[1] Despite the spread of more capital-intensive kinds of irrigation in modern times, labour-intensive forms can still be found today in large areas of the world. These are usually those where population density is high, capital scarce and employment opportunity in other sectors limited as in much of Asia (Cantor, 1967; Stern, 1979).

The radical technological changes that arose in capital-intensive irrigation were initially related to how water is captured and controlled. The construction of large dams and water distribution systems added new features to 20th century irrigation agriculture. What was important was not just the erection of dams. Fairly large reservoirs have been constructed since the early days of irrigation, but the new barrages were built to prevent the problem of sedimentation that had always been serious in the past. Since the construction of the first two modern dams, the Periyar Dam of India in 1895 and the Aswan Dam of Egypt in 1902, many other large dams have been built so that today a barrage is usually part of the landscape in an irrigation region (Cantor, 1967).

The barrages are thought to have contributed to much of the worldwide expansion of irrigation by making large-scale practice of irrigation possible. A whole new system of canals and water distribution arose as well as drainage methods. Irrigation has also benefited from the general intensification of agricultural methods. The diffusion of such industrial inputs as fertilizers, pesticides and selected seeds has permitted improved yields per area and greater labour productivity (Cantor, 1967).

Irrigation and Development Theory

Modern irrigation, as the large-scale systems based on capital-intensive technology are called, is related to public investment in enormous hydraulic projects. Since the 1950s this type of irrigation has been receiving a good deal of governmental attention as a means of bringing about rapid change in problem regions of some developed countries, such as Italy and Spain, as well as in less developed countries like Brazil, Egypt, Pakistan and Venezuela. Planners view the implanting of large-scale irrigation systems in such regions as a powerful instrument for breaking traditional rural characteristics considered to be barriers to the diffusion of modern industrial agriculture and lifestyle (Cantor, 1967; Eden, 1974; Eden & Potter, 1979; Matarresse, 1962; MINTER, 1973; Mountjoy, 1973; Thorne, 1970).

Governments hold large-scale irrigation systems in such high regard because they are the concrete expression of theories of development. For advocates of dualistic models as well as of balanced and unbalanced growth theories, large-scale irrigation can be seen as a farm technology which rapidly transforms the rural zone and integrates it into the industrial market economy. This type of irrigation is characterized by such industrial attributes as mass production and specialization. Farmers are fully orientated to the market and they possess a keen sense of profit motive and accumulative entrepreneural spirit. Such features facilitate the linkage of agricultural production to processing industries as well as creating a market for industrial inputs which, in turn, stimulates the manufacturing sector.

Opposed to this whole tendency of thought are intermediate and appropriate technology theorists, such as Schumacher (1973) and Stern (1979). These theorists advocate small-scale agriculture and are particularly opposed to the idea of capital-intensive industrial agriculture as a necessary goal. Their criticisms transcend the limited economic sphere of cost analyses and productivity measures. They question not only the long-run economic consequences of industrialization but also ecological, social and even philosophical considerations.

These theorists emphasize the positive aspects of traditional irrigation which they hold to be better adapted to the specific environmental and socio-economic conditions of the rural zone of the less industrialized countries. Stern (1979) demonstrates how environmental problems like salinization, waterlogging and erosion were well controlled in the past for the majority of the irrigated regions of Asia. These problems are more commonly encountered in large-scale irrigation systems, be they historical cases like Mesopotamia or the numerous modern cases around the world.

Those in favour of appropriate and intermediate technology irrigation systems feel that the environmental problems can be more effectively controlled by using less water and by irrigating smaller production units. The expansion of irrigation area may not be so quick but a gradual approach can allow more time to study better the difficulties that arise and to devise solutions. This is necessary in order to avoid the abandonment of large tracts of land, as has already occurred with the hasty establishment of modern irrigation around the world. Stark examples of the loss of land are encountered not only in countries like Pakistan but also in the United States and Israel.

Such concerns are not limited to intermediate technology theorists. Ruthenberg (1980) wonders whether the innovations of the last decade have increased so rapidly as to create serious problems of inadequate water control, husbandry practices and irrigation institutions. As Thorne (1970) also points out, all too often in the developing world disproportionate attention is given to planning and completion of construction details and not enough to the operation of the projects and the development of effective farming systems. This will be seen to be a large problem in public-sector irrigation of the Sertão. Innovation has been slower in the private sector, and as a result, more appropriate irrigation methods have been developed by local farmers.

Perhaps even more important than adapting irrigation to different environmental situations is matching technology type to available local socio-economic resources of labour, technical experience and capital. The availability of capital is a crucial consideration because irrigation is usually expensive to implant and operate, and capital is the scarcest resource in most developing countries.

All too often the capital-intensive farming system of North America is considered the ideal to imitate irrespective of labour and capital considerations. As Malassis (1975) has shown, the agriculture of countries such as the United States, Canada, Australia and New Zealand may be quite productive per unit of labour utilized and a large surplus is harvested but the production per area is not so high. In fact, the highest productivity per area is obtained in countries like Taiwan and Egypt where agriculture is relatively labour-intensive and productivity per worker is low. Moreover, these countries still manage to produce a considerable surplus for the urban population. There are of course countries that achieve high productivity per worker and per area as in Western Europe but the point is, as Boserup (1965) also argues, that capital-intensive agriculture is not necessarily the most efficient in the use of all factors of production nor is labour-intensive agriculture the least efficient.

Indeed, a variety of efficient choices in the combination of rural factors of production is available. Which kind of technology is best suited for any given region of the world is something that must be decided by local farmers and not be an imported package that is imposed by planners from above.

Irrigation Systems

From field research and the literature on irrigation it is possible to specify, in some detail, three ideal types of technological systems which are distinguished according to different combinations of capital, labour, farming methods and scale of production: labour-intensive irrigation, intermediate technology irrigation and capital-intensive irrigation.

1) Labour-intensive irrigation

a) Earth and rock barrages are erected with the objective of storing water to feed the fluvial courses during the dry season. Dam size can be considerable on main rivers or of more modest dimensions along smaller rivers. In addition, water may be used directly from rivers thus ruling out the necessity for reservoirs. Water is raised by manual and animal force as well as by harnessing natural forces with the use of windmills and waterwheels.

b) Main canals are built of earth and rock. Water flows by force of gravity.

c) Secondary canals are made of earth.

d) Water enters the fields by way of breaking the retaining wall of secondary canals. Water is then absorbed by the plants through inundation flooding or through infiltration with the use of furrows or sub-irrigation.

e) The amount of water required is directly controlled by the farmer who estimates the needs of each crop according to his own experience.

f) When present, drainage systems consist of simple ditches, which are sometimes lined with gravel. Excess water runs off by the force of gravity.

g) Land is prepared by manual processes and by animal traction devices.

h) Other agricultural activities are performed utilizing manual and animal traction. Organic fertilizers may be used and pests are combatted by killing them manually, with fire and with smoke. Crop rotation may be practised and long fallowing allows for the recovery of soil nutrients and soil structure as well as avoids the fixing of salt and crop diseases in the land.

2. Intermediate technology irrigation

a) A feeder dam is constructed upriver which supplies water to small dams downstream. The small dams are built with local material and technical knowledge. Water is raised with waterwheels, windmills and small mechanical pumps.

b) Main canals are built of earth, rock and brick. Water flows by the force of gravity.

c) Secondary canals are made of earth.

d) In flooding and furrow irrigation water reaches the crops by breaking the retaining wall of secondary canals. Fields are organized in basins to control and retain water. Also syphons and sub-irrigation may be used.

e) The amount of water needed is directly controlled by the farmer who estimates the amount needed for each crop according to his own experience and to information provided by extension agents.

f) Drainage is achieved with fairly deep ditches, which may be lined with gravel. Excess water runs off by the force of gravity.

g) Land is prepared mainly with animal traction devices. Mechanized equipment is only used when market conditions and capital permit and when a task must be performed quickly.

h) Other agricultural activities are performed utilizing manual and animal traction combined with some industrial techniques that complement the labour-intensive methods. Crop rotation and one to two year fallows allows for some recovery of soil nutrients and soil structure but this is done mainly to avoid problems with salinization and fixing of disease. Pesticides are employed and chemical fertilizers are used to complement organic manures (dependent on local availability).

3. Capital-intensive irrigation

a) High-capacity concrete and steel dams are built. Water passes through complex systems of concrete canals and water flow is controlled by sluices. Water is raised by powerful pumps organized in a series of sub-stations.

b) Main canals are made of concrete and to avoid problems of slope, elevated aquaducts and pipelines may be constructed in which water flows by force of gravity or by high pressure pumping.

c) Secondary canals are made of earth, concrete, brick or plastic tubing.

d) Water flows to the fields in sluice or siphon controlled secondary canals. Also sub-irrigation, sprinkling and dripping can apply water directly to crops.

e) Water flow is measure-controlled according to the exactly determined necessities of each crop and to the level of water reserves.

f) Waste water and mineral salts are removed through a network of deep drainage canals. Well pumping can also be used to remove excess water in order to prevent waterlogging. In some cases chemicals are applied to break down salts that are then drained off.

g) Land preparation is performed by tractors and other mechanized equipment.

h) Other agricultural activities are based on industrialized methods which employ motorized and electric machinery, chemical fertilizers, pesticides, and scientific crop rotation with no fallow. The use of all these inputs is precisely calculated, increasingly with the aid of computers.

Although some poor countries insist on going the route of capital-intensive irrigation, usually as show piece works that are heavily subsidized, this kind of irrigation is really more attuned to the socio-economic reality of the industrial countries. In these nations abundant capital is available to finance the high fixed investments and operating costs, high-income consumer markets exist and an elaborate infrastructure of rapid communications and economies of scale in processing and marketing reduces the price of the final product to the consumer. A whole series of external conditions are, therefore, necessary to support capital-intensive farming systems.

This runs counter to those theorists who would view the introduction of capital-intensive irrigation as a means for poor regions to achieve development more rapidly or even to skip stages. According to their view, modern irrigation would generate the conditions necessary for creating the external economies for the spread of development to other areas and activities.

Enough time has passed for the modern irrigation systems in developing countries to show their potential and the results have been dubious. Productivity may have increased with the advent of the Green Revolution - of which capital-intensive irrigation is a part - but social disparity has grown in most places as the distribution of land ownership becomes even more inequitable (Arnon, 1981; Brookfield, 1979; Griffin, 1981; Harvey et al., 1979; Pearse, 1980; Smith, 1979). Poverty continues in the regions with capital-intensive irrigation and the projects for the most part continue to be dependent on government subsidy. They are mirages of prosperity, isolated in themselves and little diffusion to the surrounding countryside occurs. They are the modern equivalent of enclaves in the old dualistic models. In some areas such systems can actually operate profitably, as Miller (1984) and Xolocotzi (1970) report for northern Mexico, but they are dependent on exporting to rich foreign markets and merely contribute to the balance of payments rather than solve agrarian problems. On the contrary, the capital-intensive systems aggravate an already volatile situation of rural poverty and disparities of wealth in less industrialized countries.

All of this does not mean that irrigation cannot be practised in the less industrialized countries. Irrigation can be exploited perfectly well when it conforms to local environmental, economic and social conditions. Local resources have to be employed to the maximum and not merely shunted aside in favour of an imported package. In particular, existing labour has to be utilized to stem the tide of rural exodus and unemployment, and local experience must be drawn upon in order to contribute to the adaptation of any introduced technology.

Not all modern techniques are automatically ruled out but a selection must be made and not simply blind imitation be followed. This latter is usually the case because top-down development strategies prevail. Planners, economists and agronomists receive their training in the industrial countries or in the developed areas of the countries in question.

When selecting new methods that can use the local resources and economize scarce capital it would seem that an intermediate technology can be more easily adapted to the socio-economic conditions of a variety of developing countries and would best mediate the urban-rural divide in such a way as to contribute to the development of both the industrial and rural sectors. With the State aiding the provision of indispensible industrial technical items the rest of intermediate technology is readily accessible to most peasant farmers. The flexibility inherent in these systems means that productive strategies can be adjusted to fit regional and national market conditions, thus ensuring a profit even when cropping low priced staples. More jobs are created because labour-saving devices are used sparingly. This is important because unemployment and underemployment are often the most serious problems encountered in developing countries. So, with more modest investment costs, it is possible to have a system better atuned to local conditions and hence more readily diffusable to the majority of farmers. Instead of aggravating existing problems and creating new ones, as occurs with the indiscrimate introduction of capital-intensive systems, intermediate technologies do more to promote rural development.

3. THE DILEMMA OF DROUGHT

Drought and efforts to develop the Sertão have been traditionally intertwined. This occurs because farming is the base of the Sertanejo economy and this activity is profoundly affected by the semi-arid climate of the zone. Hall (1978) and Katzman (1984) are no doubt correct in saying that environmental difficulties are too often cited as being the cause of the underdevelopment of the Sertão, but this does not alter the fact that ecological considerations are still important.

This is particularly true for semi-arid zones. As Dregne (1970) has observed, periodic drought and other climatic disruptions are more serious in semi-arid zones than even in arid ones. The ecological potential of semi-arid regions for farming is favourable enough to attract a relatively large population whose cropping activities get them by in most years but harvest failure is consistently experienced in years of poor rainfall.

This is clearly seen in the Sertão. Drought is most disruptive where semi-arid conditions prevail. In these places population density is higher and reliance on rain-fed cropping is greater than in more arid ones. Stock-raising is the focus of rural activities in drier parts of the Sertão and it is less vulnerable to drought. Furthermore, landless peasants are those who most feel the impact of drought and there are few present in stock-raising areas.

Much of the climatic variation of the Sertão is found in the study area. The principal irrigation area is located on the main stream of the São Francisco River and lies in a depression that was cut by the river. To the north, climatic conditions become increasingly more favourable for the practice of rain-fed cropping as one approaches the Chapada do Araripe and other highland areas which form the state boundaries between Pernambuco, Piauí, Ceará and Paraíba. Rainfall increases and the climate gradually shifts to a semi-humid one. In parallel, the traditional land use systems shift from a stock-raising focus to a cropping focus as one moves north. In strong contrast, the southern half of the study area is one of the most arid areas of the Sertão. Rainfall is quite low and erratic so that extensive stock-raising is the main pursuit.

THE CLIMATIC BASIS OF DROUGHT

A great deal of climatic variation exists in the Northeast. The eastern and western parts of the region are very humid while the central part - the Sertão - is quite dry in comparison.

While some spatial variation exists for temperature in the Northeast, it is not very great. Temperatures in the whole region are high throughout the year, with an annual average of between 23°C and 27°C. The difference between average annual maximum and minimum temperature is only 5°C to 10°C.

Somewhat greater variation between humid to dry zones is observed for rate of insolation but high readings are registered throughout the Northeast because of its close proximity to the Equator. In humid zones insolation is about 2300 hours per year, there are 6.3 hours of sunshine per day and relatively high potential rates of evaporation result, about 1200 mm per year. In the Sertão insolation is approximately 2800 hours per year, there are 7.7 hours of sunshine per day and a still higher potential rate of evaporation prevail, about 2000 mm per year (SUDENE, 1979).

The climatic element that varies most in the region is rainfall. Precipitation varies from an average of more than 2000 mm per year in some places to as little as 250 mm in others. The limits of the Sertão are roughly defined by the zones with under 750 mm of rainfall, corresponding to about half of the area of the Northeast (Figure 3).

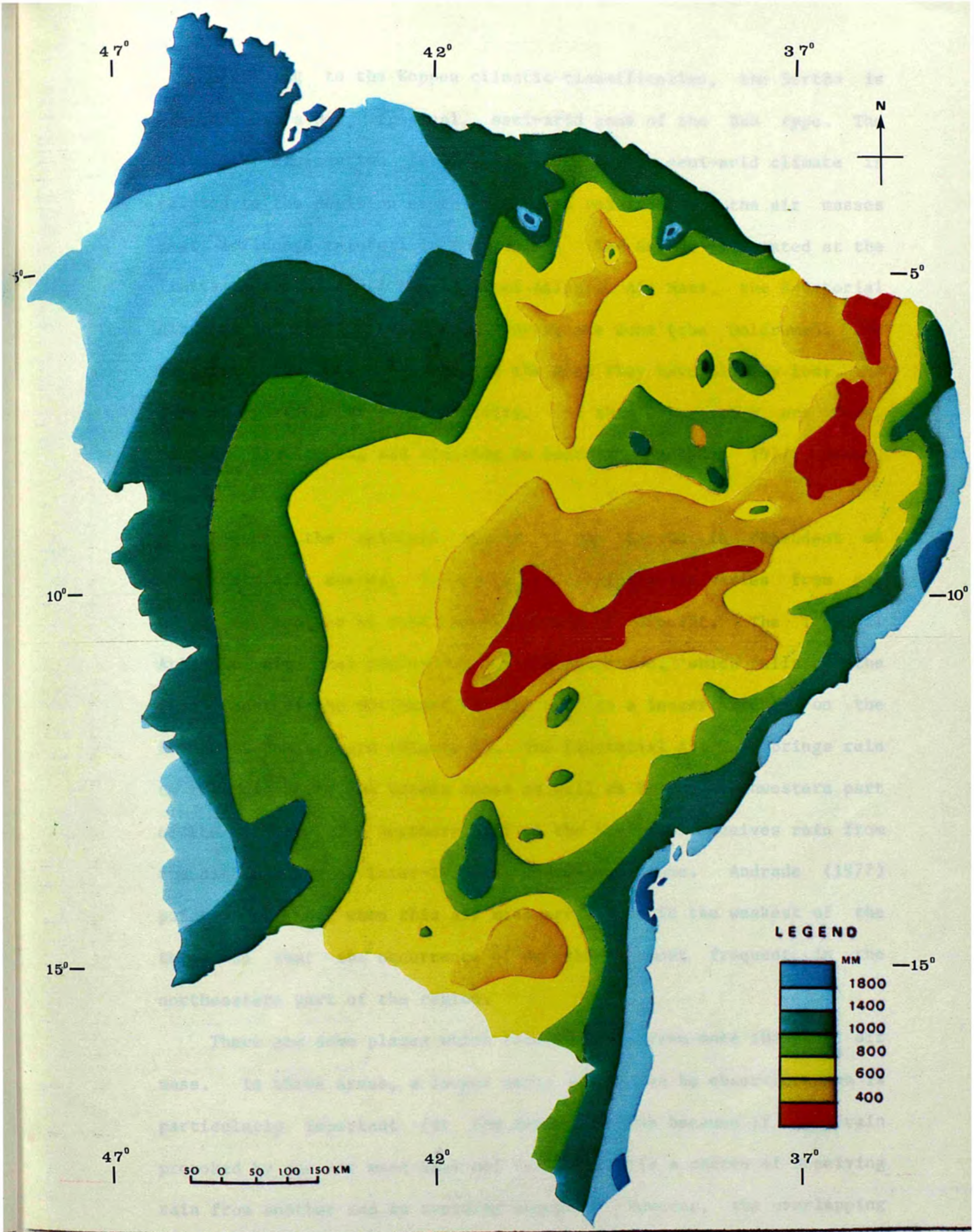
In the humid Zona da Mata and semi-humid Agreste zones on the eastern seaboard, rainfall is usually concentrated in six months of the year, so that a dry and a rainy season are well defined. The western transitional zone to the Amazon region, the Meio-Norte, also has a humid climate but with a six to ten month rainy season. The annual average relative humidity of all of these zones is 83% (SUDENE, 1979).

In contrast, the Sertão has an annual average relative humidity of 50%. Precipitation is restricted to three to five months of the year and can be quite concentrated, falling in the space of a month or even of days. This irregular and unpredictable distribution of rainfall is one of the principal causes of an historical pattern of recurrent drought (Table 1).

Table 1. Recorded Droughts.

1500s	1600s	1700s	1800s	1900s
1499-1500	1603	1707-1711	1803-1805	1902-1904
1559	1614-1615	1720-1721	1808-1809	1907-1908
1564	1651-1652	1723-1724	1814	1915
1583	1692-1693	1735-1737	1816-1817	1919
1592		1744-1746	1819-1820	1931-1933
		1748-1751	1824-1825	1936
		1754	1827	1941-1944
		1760	1829-1830	1951-1953
		1766	1833-1835	1958
		1771-1772	1837	1970
		1776-1778	1845-1846	1975-1977
		1783-1784	1860	1979-1983
		1790-1794	1868-1869	
			1877-1879	
			1885	
			1888-1889	
			1891	
			1898-1900	

Source of Data: Santos (1962), MINTER (1973) and Field Research.



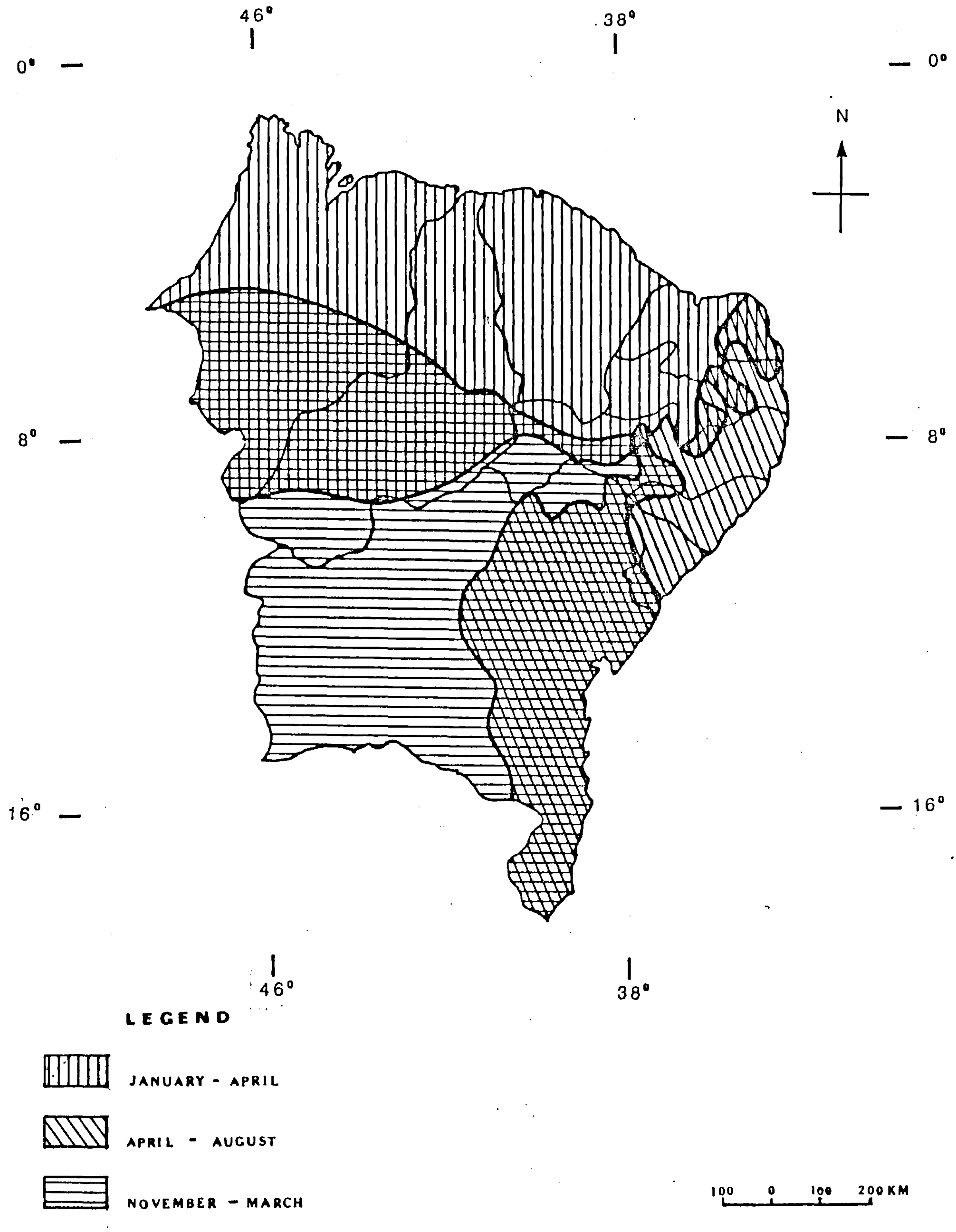
After: Melo (1978).

Figure 3. Precipitation Patterns in the Northeast.

According to the Koppen climatic classification, the Sertão is classed as a hot, tropical, semi-arid zone of the Bsh type. The principal explanation for the existence of the semi-arid climate is related to the position of the Sertão in relation to the air masses that influence rainfall in the region. The Sertão is located at the limits of influence of the Tropical Atlantic Air Mass, the Equatorial Air Mass and the Inter-Tropical Convergence Zone (the Doldrums). By the time the masses arrive in the area they have already lost the greater portion of their humidity. At this point they are weak, already dissipating and starting to retreat (Andrade, 1977; Nimer, 1966).

Because the rainfall system in the Sertão is dependent on different air masses, the period of precipitation varies from one place to another as does the likelihood of drought. The Tropical Atlantic Air Mass provokes heavy precipitation, which falls on the East Coast of the Northeast as well as, to a lesser extent, on the Sertão of Bahia State (Figure 4). The Equatorial Air Mass brings rain to the Meio-Norte and Gerais zones as well as to the southwestern part of the Sertão. The northern half of the Northeast receives rain from the air mass of the Inter-Tropical Convergence zone. Andrade (1977) points out that when this air mass arrives it is the weakest of the three so that the occurrence of drought is most frequent in the northeastern part of the region.

There are some places which receive rains from more than one air mass. In these areas, a longer rainy season can be observed which is particularly important for the Semi-Arid Zone because if the rain provoked by one air mass does not fall, there is a chance of receiving rain from another and so avoiding drought. However, the overlapping of air masses at the farthest reaches of the systems must not be



Source: Andrade (1977).

Figure 4. Periods of Rainfall in the Northeast.

emphasized too strongly. In any given year, one or all of the masses may not reach their maximum extension thus causing little or no rain to fall.

Relief is another factor which effects precipitation patterns. The whole Sertão is a rolling erosional plain which lies in a depression between the Borborema Plateau to the east and the Central Plateau and the Plateau of Piauí to the west. Of these plateaus the one which most interferes with rainfall in the Sertão is the Borborema Plateau. It acts as a barrier to the humid winds of the Tropical Atlantic Air Mass. Rains fall on the eastern side of the plateau while the western side becomes drier and drier towards the interior. This creates a rain shadow behind the plateau and the lowest precipitation readings of the Sertão are registered there.

The same occurs within the Sertão. Highland areas are called 'green islands' because they receive a greater quantity of rainfall more regularly, than do other parts of the Sertão while rain shadows occur in areas located between mountain ranges.

Rainfall varies greatly in the study area with the average annual precipitation ranging from less than 400 mm in the southern part (Chorrochó, Patamuté and Várzea da Ema), to 400-600 mm in the part along the São Francisco River (Petrolina, Cabrobó, Belém do São Francisco) and to 600-800 mm and more in the most northerly sector of the area (Exu, Parnamirim, Salgueiro)(Table 2).

Rainfall is strongly concentrated in a few months of the year and even in the space of a couple of days (Tables 3 and 4). This is more marked in the southern part of the area where rainfall is concentrated into one or two months of the year. Most dry farming crops need from two to three months of regularly dispersed rainfall so that the risk of harvest loss is highest in the southern half of the study area and decreases as one moves north. This explains why ranching is more important in the south and cropping increases as one moves north. Nevertheless, even in the North, 20 day gaps in precipitation frequently occur which result in crop failure.

Table 2. Average Monthly Precipitation in the Study Area (mm)(a).

Locality	J	F	M	A	M	J	J	A	S	O	N	D	Total
Exu	97	137	178	125	86	41	31	16	10	28	51	71	911
Parnamirim	86	114	144	77	31	11	9	3	4	17	37	57	581
Salgueiro	85	110	154	71	27	9	8	4	6	17	36	57	576
Petrolina	57	76	98	47	8	4	3	2	4	13	46	64	410
Cabrobó	61	88	105	60	18	14	9	3	4	10	40	71	487
Belém S.F.	63	70	100	58	22	14	7	2	3	13	51	32	435
Chorrochó	57	57	86	45	16	7	6	1	5	7	41	39	376
Patamutê	46	62	71	46	21	10	7	3	4	15	26	44	356
V. da Ema	47	67	90	51	30	22	14	6	7	11	48	58	449

Source of Data: SUDENE.

(a) Period of meteorological observation: Exu (1934-1981), Parnamirim (1911-1970), Salgueiro (1911-1981), Petrolina (1911-1977), Cabrobó (1911-1970), Belém do São Francisco (1914-1981), Chorrochó (1938-1979), Patamutê (1911-1981) and Várzea da Ema (1936-1981).

Table 3. Percentage of Average Monthly Precipitation which Falls in a 24 Hour Period in the Study Area

Locality	J	F	M	A	M	J	J	A	S	O	N	D
Exu	36	49	27	30	34	41	37	51	61	60	48	42
Parnamirim	42	36	36	39	58	51	62	56	80	63	51	45
Salgueiro	43	36	41	44	49	52	62	65	73	65	57	55
Petrolina	50	40	39	56	70	64	72	70	94	63	48	45
Cabrobó	50	38	38	50	46	63	53	61	90	70	47	41
Belém S.F.	34	29	24	32	30	34	45	45	57	37	35	55
Chorrochó	55	54	44	52	51	83	58	67	92	66	55	55
Patamutê	48	39	41	48	49	57	55	81	89	73	60	54
V. da Ema	50	49	36	42	41	39	42	50	62	61	45	55

Source of Data: SUDENE.

Table 4. Average Number of Days per Month with Rainfall in the Study Area.

Locality	J	F	M	A	M	J	J	A	S	O	N	D
Exu	5	5	7	5	5	3	2	1	1	1	2	3
Parnamirim	5	7	8	5	3	2	2	1	0	1	3	4
Salgueiro	6	7	8	5	3	2	1	1	1	1	2	4
Petrolina	4	5	5	3	1	1	0	0	0	1	3	5
Cabrobó	5	6	7	4	3	3	2	1	0	1	3	4
Belém S.F.	4	4	6	4	3	2	2	1	1	1	3	3
Chorrochó	3	3	4	2	2	1	1	0	0	1	2	2
Patamuté	3	3	4	3	2	1	1	0	0	1	1	3
V. da Ema	4	4	6	5	5	5	4	2	1	1	3	4

Source of Data: SUDENE.

Average annual temperature readings in the study area are somewhat above average for the Northeast, ranging from 24° to 27°C. Less variation through the year is also observed, with the difference between average monthly temperature being from 3° to 5°C. These temperatures are high but they are not excessive for tropical crops.

Cloud cover is low throughout the year. In Cabrobó, for example, on average only 38 days a year are completely overcast (SUDENE, 1963). The amount of available sunlight is high, which contributes to the rapid growth of crops. Data on insolation are not available for the study area but local conditions are similar to those found in the rest of the Sertão, so that rates of insolation of 2800 hours per year also make conditions ideal for cropping.

However, consistently high temperatures, low cloud cover and high rates of insolation contribute to high rates of evaporation, which pose serious problems in a region where rainfall is low. Winds are fairly weak throughout the year, e.g. 3.0 m/sec on average was observed in Cabrobó (SUDENE, 1963). Nevertheless, they are constant, which further contributes to evaporation. In addition, relative humidity is also consistently low throughout the year. In the three localities along the São Francisco River for which data are available, the maximum monthly average relative humidity is seldom above 70%. During the dry season, when temperatures are highest, the relative humidity drops to between 55% to 65% in Cabrobó, to between 57% and 71% in Petrolândia and to 34% and 43% in Petrolina.

The period of highest temperatures and lowest relative humidity coincides with the time of the year when evaporation is highest. Experiments carried out by EMATER (1975) in Salgueiro registered monthly potential evaporation rates of 244 mm in August which rise to 314 mm in December (Table 5). The rate decreases to 233 mm in January and February and then to between 153 and 195 mm for the months of March to July.

Table 5. Monthly Average Rainfall and Potential Evaporation in Salgueiro (mm).

	J	F	M	A	M	J	J	A	S	O	N	D
Rainfall	74	93	127	63	21	10	6	3	2	11	31	41
Pot. Evapor.	233	233	214	153	190	156	195	244	275	279	268	314
Deficit	159	140	87	90	169	146	189	241	273	267	237	273

Source of Data: EMATERPE (1975).

Two important consequences for farming stem from this high rate of evaporation. One consequence is the need to water crops more frequently. Even during the rainy season most crops must be irrigated from one to two times a week and during the dry season this increases to three to four times a week. This increases costs and depletes water reserves, especially during the dry season when they are lowest. Secondly, the amount of water which evaporates exceeds the amount of rainfall in most of the Sertão. This means that water for irrigation, livestock and domestic purposes must flow from elsewhere and water storage capacity must be great enough to allow for substantial loss from evaporation.

Thus, a number of climatic factors, such as irregular rainfall, constant high temperatures and elevated rates of evaporation, limit the supply of water throughout most of the year, which can lead to crop failure, death of livestock and shortage of water for domestic needs. This, in turn, has traditionally led to widespread famine and out-migration. Even today, the incidence of drought continues to cause grave disruption in the Sertão.

GOVERNMENT EFFORTS TO COMBAT THE EFFECTS OF DROUGHT

While some change in strategy has occurred with time, government policy for the Sertão has been traditionally focussed on the drought problem. Three periods of public involvement can be distinguished. Before 1850 the government took a laissez-faire approach to the problems of the Sertão. From 1850 to about 1970 public action gradually assumed an indirect character of involvement, which focussed on building roads and reservoirs. The aim was to store ever greater amounts of water and to allow for faster transport of food supplies and evacuation of refugees in times of drought. Since 1970 the government has been pursuing more of a direct intervention strategy. This involves attempting to transform the agrarian system of the Sertão through the establishment of public irrigation projects.

Before the 1850s the central government took scant notice of the plight of the Sertão. Little was done and this usually only dealt with the immediate problems of water scarcity and food shortages. Long-term government action was limited to opening deep wells from 1831 onwards (Souza, 1979). Other than this, preventative action was taken only by private initiative at the farm level, with one or other wealthy rancher building a reservoir.

The year 1856 marks a watershed for the Northeast when the Comissão Científica de Exploração was formed to study the problems of the Semi-Arid Zone. Its recommendations are responsible for the earliest ideas on how to deal with the difficulties created by drought. For the first time, lack of water and crop failure were examined together with other socio-economic problems of the zone. The installation of weather stations was suggested in order to forecast the occurrence of drought. Reservoirs were needed not only to ensure water supply but also to provide food through their use for irrigation and fishing. A good road system would be needed for the faster transportation of goods and people both during drought and in normal years (Souza, 1979).

It is thus evident that the need for reservoirs, irrigation works, fishing and transport improvement was present in even the earliest ideas on how to solve the regional problems. If only a few of these measures had been taken at that time, the regional economy could have been modified to make it less vulnerable to drought. New rural activities would have been introduced and the construction of roads would have improved access to local and regional markets, thus permitting the growth of farm production.

However, nothing concrete was done. Studies and suggestions were merely put down on paper. A preliminary plan to build thirty reservoirs and to improve transport and communication facilities was never implemented. Despite all the studies the region continued to be as unprepared as ever and at the mercy of the droughts. And the worst happened. Shortly afterwards, one of the most serious droughts in Brazilian history ravaged the region. The Great Drought of 1877 lasted for three years and the scale of destruction left in the aftermath was considered a national catastrophe.

One can judge how serious this drought was by the large-scale exodus of population and loss of life. MINTER (1973) estimates that in 1877 a total of 1,754,000 inhabitants lived in the Semi-Arid Zone. Almost half of them, 800,000, lived in Ceará State and of this population, 112,000 persons fled from the dry interior to the state capital Fortaleza on the coast. Of the refugees that arrived in Fortaleza 55,000 emigrated to the Amazon region or to other regions and the rest, 57,000 persons, died in the capital because of the lack of resources with which to help them. So almost 7% of the state population perished in the capital, not counting the number of people who suffered the same fate on their way. Also, a great number of the 55,000 persons who emigrated from Ceará probably died from disease and starvation in the Amazon (Facó, 1976). It is not possible to know for sure exactly how many deaths occurred during those three years throughout the Northeast, but without doubt it was a much higher than the 7% recorded for Ceará. Hall (1978) and Souza (1979) cite Lisboa's estimate of 500,000 people, or roughly one-third of the population of the zone.

This calamity managed to attract the attention of the central government. New measures were established to study the region and suggestions were made for government action. Once again, more research was undertaken but very little was done in practical terms. Sporadic assistance to drought victims during the periodic crises continued as always. When news of a serious drought reached the central government, food was purchased where available and dispatched to the state capitals of the Northeast for distribution to the victims. Unfortunately the consignments often took too long to arrive, which meant starvation for many refugees. The aid of state governments for the drought victims usually consisted of free ship transport to the Amazon region and to other pioneer areas (Facó, 1976; MINTER, 1973).

The first public work projects finally began in 1884 when a detailed study was made for the construction of the Cedro reservoir in the county of Quixadá, Ceará State. Work on the project began in 1888 and the reservoir was only completed in 1906. The project also included an irrigation network, which demonstrates the preoccupation with irrigation even at that time. So the objective was not merely to supply water but also to make use of the water for agricultural purposes. However, this attempt at irrigation failed because the reservoir water was highly saline, which in turn ruined the soil so that irrigation was subsequently abandoned (Hall, 1978; MINTER, 1973; SUDENE, 1979).

Government action during this period was quite limited. Too much time was spent on studies, with little actually being done to solve the problems. However, scarcity of public funds was always a barrier. Moreover, the 19th Century was a period of great socio-economic and political change in Brazil, which profoundly affected the policies for improving life in the Northeast. The most relevant events were the increasing power of the South, the Paraguay War and the Proclamation of the Republic.

The change in the economic dominance of the country by the sugarcane planters of the Northeast to that by the gold mine and coffee plantation owners of the Southeast brought with it a change in the focus of political power. The national capital was moved from Salvador in the Northeast to Rio de Janeiro in the Southeast. Losing its political and economic importance, the Northeast became increasingly dependent on the Southeast and gradually acquired a peripheral status. A natural flux of resources from the North to the South followed. With the political centre in the South, the growth of its economy was considered more important than that of the North as it was deemed to be crucial for increasing the authority of the central government (Albuquerque, 1981; Flynn, 1978; Furtado, 1973; Melo, 1984; Oliveira, 1977). The outflow of capital and increasingly restricted access to public funds meant that the economy of the Northeast languished and in particular less funds were available for financing public projects in the Sertão.

The Paraguay War in 1864-70 had strong negative repercussions on the whole Brazilian economy by heavily endebting the national treasury which, in turn, further hindered government investments in public works in less important regions (Chiavenatto, 1979). Within this financial context the abolition of slavery took place in 1888. This meant that labour used in government projects had to be paid for, thus raising the cost of works and worsening the lack of capital problem.

Then, in 1889 the Empire was overthrown and substituted by the First Republic. The new government was established in the South, as its predecessor and was confronted by dissident groups, particularly in the Northeast. The total centralization of political power in the South was one way to guarantee the strength of the new regime and the unity of the country (Albuquerque, 1981; Facó, 1976; Flynn, 1978). In this context, investment in other regions would have been viewed as merely strengthening potential rivals and so the federal government was even less inclined to undertake works in the Northeast. Facó (1976) cites another policy of the new government which further worsened the financial situation of the country and of the Northeast in particular. In an attempt to resolve the crisis of the national treasury the new administration replaced the gold standard with paper money. This provoked high inflation as no proper control was retained over the amount of currency printed.

Thus, by the end of the 19th Century, little material aid had actually been applied in the Northeast, but the 1800s did provide an important legacy. Several studies of and expeditions to the Semi-Arid Zone were undertaken by different government commissions and hence some observation and analysis of the complexity of the problems involved with drought were made. These studies were the first systematic research carried out in the region and they were the basis for planning and executing many of the projects that were later established. Even today, the studies continue to be useful and they still influence contemporary research and construction of public works (MINTER, 1973).

Despite the fact that many of the basic problems with drought had been recognized for nearly 50 years, concrete efforts to remedy the situation only really began after 1900. As usual, new government action was taken only after another serious drought in 1900. In the first years of this century the plight of the Sertão began to be formally treated as an economic question of national importance. Public agencies were established to deal with the specific difficulties of the region. A new budget policy was implemented, which made funds from the national budge available for combatting the droughts on a permanent basis, and this was formalized by law in 1904.

Three commissions were created to administer the public works projects: the <u>Comissão de Açudes e Irrigação</u>, the <u>Comissão de Estudos e Obras Contra os Efeitos das Secas</u> and the <u>Comissão de Perfuração de Poços</u>. Shortly afterwards, the three agencies were united into one bureau, the <u>Superintendência dos Estudos e Obras Contra os Efeitos das Secas</u>, that one year later had its name changed to the <u>Comissão de Açudes e Irrigação</u>, which it retained from 1905 to 1909.

The Commission was reponsible for the planning and construction of several dams as well as for the drilling of a number of wells. In 1906, it also put an end to the Cedro reservoir project which had been dragging on for sixteen years. The project was a failure and other projects fared even worse, which provoked a general evaluation of the Commission's work in 1907. It was concluded that the costs involved with the construction of the reservoirs were exceedingly high and that many of the dams built did not withstand the flash floods of the Sertão. Some of the reservoirs and dams were poorly designed, others presented defects of construction and still others were badly maintained (Pinheiro, 1959).

MINTER (1973) holds that the most serious problem of the period involved the use of experience from other countries without the necessary adjustment to local conditions. To make matters worse, little data existed on the Sertanejo environment. No pluviometric records were available, which seriously compromised the success of the dams. The barrages designed by foreign engineers with little prior experience in tropical semi-arid zones and so the dams were carried away by the first flash flood.

The recognition of the above problems and the need for more than just isolated public dams, caused the substitution of the Commission by yet another agency. In 1909, the Commission was abolished and replaced by the Inspetoria de Obras Contra as Secas (IOCS). The general objective of the new agency was the same as that of its predecessor. It was entrusted with enabling the region to better cope with drought. However, some new programmes were added. The agency was also empowered to build roads and railways, install meteorological and pluviometric stations, and to carry out geological, topographical and botanical research. Another objective was an educational programme in order to form a middle level of trained personnel in the region (Souza, 1979).

In 1919, IOCS was re-named the Inspetoria Federal de Obras Contra as Secas (IFOCS) and retained this name until 1945. Despite the wide scope for action of IOCS/IFOCS, the agency concentrated mainly on roads and reservoir projects. Research on the physical conditions of the Sertão continued to be carried on but studies of the economic and social situation in the zone and actions directed at these type of problems were given low priority (Hall, 1978; MINTER, 1973; Souza, 1979). When such questions were considered at all they were treated as an appendix of other actions. For example, one way to assist the population during drought years was by offering low paid jobs in the construction projects that were in progress.

With attitudes like these the agency never achieved its objectives and the region remained unprepared for drought. Much more needed to be done to improve the local conditions of life which was not accomplished by merely providing water, roads and temporary jobs. The socio-economic structure remained unaltered and continued to show its basic weaknesses in crisis years. The transformation of the local economy, particularly of the land use and tenure system should have been urged. This became increasingly evident with rising demographic pressure. The growing imbalance between the overall population and the available resources, as well as the inequitable distribution of these, were the crucial issues which needed to be addressed.

Nevertheless, the basic error of overemphasizing the building of roads and reservoirs can be explained logically. Moreover, IFOCS cannot be held solely responsible for this. Local and national political and economic factors of the times influenced the policy of the agency.

The lack of financial support was always an obstacle. In addition, the irregularity of payments made matters worse. Hence, financial difficulties could have been an excuse for choosing only one part of the whole programme to be implemented. Nevertheless, it seems that IFOCS limited its actions to roads and reservoirs for three main reasons.

Firstly, the poor conditions of transport were a great barrier for any type of public action to be undertaken. The non-existence of roads or the existence of a few poor ones in some areas made the construction of reservoirs and drilling of wells a hard task. Technicians, tools and materials only arrived at the construction sites after great hardship and high expense.

Secondly, the preoccupation of IFOCS with reservoirs and roads, in turn, caused its personnel to be made up almost exclusively of civil engineers and similar staff (Souza, 1979). This became a vicious circle because even when such technicians realized the importance of socio-economic factors they lacked both the training and the experience to do much about them. In addition, this type of personnel in Brazil usually hold the assumption that after the completion of their projects, socio-economic change comes about naturally. Social constraints and barriers to change, other than ignorance attributed to rural folk, is simply unknown to them. Moreover, numbers are all that matter. Hall (1978) shows how in practice the success of the various engineers who headed IFOCS (and later DNOCS) was measured in terms of the amount of water stored in reservoirs during their time in office. In addition, it should be pointed out that they were only worried about quantity of water and rarely with its quality.

The third factor to be considered is the political situation of the times. IFOCS was created in the first years of the Republican government. The new government had to silence dissident groups that threatened its power. Many of these groups were found in the Northeast and the region was the scene of several revolts. Bandits and powerful land-owners also menanced government authority. To resolve these questions in such a way as to enhance the power of the central government, isolated areas needed to be integrated by roads and railways so as to enable greater police and judiciary control (Facó, 1976; Queiroz, 1977). Moreover, roads and reservoirs are highly visible public works which made good political capital for regimes in search of popularity.

Regional politics also worked against public intervention into the agrarian structure. Hall (1978) points out that the IFOCS personnel had close ties to large land-owners who were already antagonized enough by the expropriations that were needed to build reservoirs. Needless to say such individuals would not accept further expropriations in order to establish land colonization projects. It should be added that rural interests dominated most Northeastern state governments well up to the 1960s. Even today many civil service jobs are awarded on a political clientage basis in the Northeast so that anyone who goes against the powers-that-be can lose his job. Thus, various types of pressures came to bear on IFOCS policy causing the agency to emphasize certain lines of actions in detriment to others.

Once again, after the serious drought of 1930-32, new policies were introduced. Images of the destruction and suffering caused by the drought, such as the widespread loss of crops and livestock, famine, mass emigration and even death were made more vivid by improved communications and served as a reminder that the same thing could happen again if something was not done. Roads, dams and irrigation were given priority.

The new transport scheme had a novel feature which distinguished it from previous policy. The emphasis changed to building main roads instead of railroads. The principal trunk routes of the Northeast were built during the 1930s and 1940s and they were meant to link the main regional cities to one another as well as to connect the Northeast to the Southeast. Besides facilitating shipment of emergency supplies in time of crisis, improving intra- and inter-regional transport systems was also viewed as a way for farmers to gain access to potential markets. The new roads were held to be crucial for stimulating the economy of the Northeast and for guaranteeing the success of the irrigation programme to be introduced (Souza, 1979).[1]

The government irrigation policy for the Northeast focussed on the Sertão. The objectives were to increase agricultural production, to raise farmer income and to create local markets. The programme was to follow two lines of action. One was the installation of experimental irrigation farms and the other consisted of a public cooperation scheme to coordinate measures for promoting the spread of private-sector irrigation. The various ramifications of this programme are treated in greater detail in Chapter 5 but it can be said here that the programme was not a success. Once again, too little was done and public funds to finance the various schemes were never allocated on the scale originally envisaged. It was also evident that, due to the high production costs involved, irrigation would never be adopted on a large scale until a basic rural infrastructure was implanted and a large consumer market arose.

One novel approach that came out of this period was the first targetted integrated development project. Following the American example of the Tennessee Valley Authority, the Brazilian government realized that the São Francisco Valley had great potential which could be developed under a similar plan. A programme was established which called for the development of fluvial navigation, hydro-electric sites and irrigation projects. To this end, in 1938, a study group was created within IFOCS, the *Comissão do São Francisco*. In later years, the same approach was envisaged for the Jaguaribe and Açu Valleys, though, in these cases only preliminary studies were made (SUDENE/ASMIC/IJNPS, 1967; SUDENE, 1964).

In 1945 IFOCS was reformed and its name change to the Departamento Nacional de Obras Contra as Secas (DNOCS), the name by which it is known today. The reorganization of IFOCS brought about the creation of two other independent agencies in 1948. One was the Companhia Hidroelétrica do São Francisco (CHESF) which assumed responsibility for the construction of hydro-electric projects along that river. The other agency was the Comissão do Vale do São Francisco (CVSF) that was entrusted with the economic development of the valley.

From that time on, irrigation on reservoirs came under the jurisdiction of DNOCS while irrigation along the São Francisco River was the responsibility of CVSF and their respective work developed independently of one another. However, not much was done by the agencies from that time until the late 1960s. DNOCS maintained its few experimental farms and, after serious droughts in 1952 and in 1958, new emphasis was given to the construction of large reservoirs. In the meantime, CVSF, later re-named the Superintendência do Vale do São Francisco (SUVALE), continued detailed research in its area, mainly of the soils, with special attention to their potential for irrigation.

The 1950s were a time of further consolidation of institutions for studying regional problems and planning development. The Banco do Nordeste do Brasil was established in 1952 with its head office in Fortaleza. The main function of the bank was to provide credit but it also sponsored economic research in the Northeast, and irrigation in the Sertão was a priority theme. These studies were different from previous ones as they focussed on the social and economic problems of the region and their relationship with the environment. The study made of private-sector irrigation that was developing along the São Francisco River (Banco do Nordeste, 1957) is still one of the few empirical studies to have been done on the subject in the Sertão.

Another study group of the period, the Grupo de Trabalho do Desenvolvimento do Nordeste (GTDN), reached the conclusion that a regional planning agency for the whole Northeast should be established in order to better coordinate public and private actions. In 1959, the Superintendência do Desenvolvimento do Nordeste (SUDENE), came into being and its main office was located in Recife.

A number of ambitious agrarian and industrialization policies were contemplated. The four principal goals were: a) to intensify investments in manufacturing in order to create an independent industrial centre in the Northeast, b) to transform the rural economy of the humid zones in order to supply staples to the growing coastal cities, c) to progressively transform the Semi-Arid Zone in such a way as to raise farm productivity and to make the zone more resilient to drought and d) to colonize the frontier areas with the population freed by the process of reorganizing the Sertanejo economy (MINTER, 1973; Souza, 1979).

However, most of the actions of the new agency were focussed on promoting the industrialization of the Northeastern capitals. The agrarian policies either failed, were never implemented or were so limited in scope as to reach only a minority of farmers. The colonization of pioneer areas was a failure. Reorientation of rural activities in the humid zones toward the production of staples and agrarian reform were never seriously undertaken due to political pressure by powerful land-owners, especially after the military coup of 1964. The various plans to transform the Sertão only reached a small minority of farmers.

Most of the funds made available to the private sector in SUDENE's farm programme of special loans and tax credits went exclusively to large land-owners in humid and semi-humid zones, i.e. exactly those who are least affected by drought. Even the lion's share of the funds of integrated development projects, such as the Projeto Sertanejo, have gone to wealthy farmers. This occurred both because SUDENE has been 'captured' by the regional elite (Oliveira, 1978) and because these farmers are those "who were thought to have the financial means and technical know-how to make best use of the funds ... [while] giving assistance to smallholders had to wait for a later phase" (Souza, 1979: 257). This was confirmed in the field research area as well as in the general survey. Only in the last four years have other land-owners been able to receive some of these loans and this occurred mainly because federal policy became less biased in favour of large capitalist farmers (empresários).

One of the proposals for the transformation of the agrarian structure of the Sertão was the introduction of irrigation. SUDENE took the initiative in not only executing elaborate studies of the important river valleys of the Sertão but also in setting up the first two large public irrigation projects, Morada Nova in the Jaguaribe basin and Bebedouro along the São Francisco River. It later turned these over to the respective irrigation agencies (Hall, 1978; MINTER, 1973). However, as will be shown in later chapters, the public-sector irrigation projects have not lived up to expectation and have only reached a small fraction of Sertanejo farmers.

SUDENE also took over the administration of public work projects (frentes de trabalho) executed during droughts with the aim of holding the affected poor population in the region. This practice began during the drought of 1930-32 when 270,000 workers were employed and has been more-or-less maintained in the same pattern to date. Workers still make structural improvements on roads, reservoirs and public irrigation projects. During the drought of 1958 about 500,000 workers were employed, 500,000 workers in 1970 and 280,000 workers in 1976 (Hall, 1978; Souza, 1979). These stop-gap actions have significantly reduced the drought induced out-flux of refugees of the past. In addition, market integration and transport improvements have reduced the famine conditions of former times when from one-third to one-half of the Sertanejo population starved or perished from disease during prolonged, serious droughts.[2]

While much has been accomplished to reduce the impact of drought more remains to be done. The number of workers enlisted for public works and the reduction in Northeastern farming output during droughts indicates this. The proportion of individuals employed in public works to the total farm work force of the zone may have dropped from about 32% of the total in the 1958 drought to approximately 27% in 1970 and to about 15% in 1976 but even the latter figure is still unacceptably high. Also, the farming system of the Sertão is still vulnerable to drought and this continues to weigh heavily on the regional economy. Souza (1979) reports that overall Northeastern farming output dropped by 10% in the 1951 drought, by 10% in 1958, 17% in 1970 and 7% in 1976. Thus, all the different measures taken by the government have not yet really got to the root of the problems. As will be shown in the next chapter, the agrarian system throughout most of the Sertão has not changed fast enough in order to overcome the basic environmental and socio-economic problems.

In fact, as much of this history indicates most of the efforts made and funds spent have been on urban bureaucratic organization rather than rural infrastructure. Gordon (1972) shows that the liberal, indirect approach to public involvement often results in this type of waste. Large sums are consumed in the administration of government programmes which reduces the funds available for those who are supposed to benefit from them. This without doubt occurred in the Northeast but this will be shown to be even more of a problem in the direct intervention approach. The root of the problem is the urban-industrial bias of Brazilian development planning and its top-down nature so that this will have to be changed if any government farm programme is to succeed.

4. DRY FARMING IN THE SERTÃO

Dry farming systems of the Sertão have been gradually modified over time but natural and socio-economic limitations exist which have not allowed the systems to change rapidly enough in order to overcome regional problems. Farming is still vulnerable to drought and the risk of drought itself limits change. Low farm prices do not permit the adoption of many innovations and, in the absence of intensification in the use of land, declining farm size causes income to fall over time. The small size of farms, in turn, further limits the technical options open to Sertanejo farmers. An employment crisis has resulted which has intensified rural exodus. In sum, despite some encouraging signs of change in stock-raising, the overall situation in dry farming is one of continuing underdevelopment.

While such local factors as climate and population pressure are important for explaining the underdevelopment of the Sertão, government pricing policies and international commodity price trends are the main problems. Sertanejo farmers are not alone for their dilemma parallels that faced by peasant farmers caught up in the process of market integration and penetration in the rest of Brazil, Latin America and much of the developing world in general (Arnon, 1981; Belshaw, 1964; Forman, 1975; Foster, 1973; Goodman & Redclift, 1981; Hunter, 1969; Lipton, 1977; Oliveira, 1975, 1977; Pearse, 1975, 1980; Warman, 1982; Wolf, 1966, 1982; Yudelman & Howard, 1970).

DRY FARMING LAND USE SYSTEMS

Historically, the land use systems which arose in different parts of the Sertão were adapted to the varying climatic and socio-economic conditions that prevailed in former times. Each combination of farm activities was one that, given the conditions of the time, could, in most years, best withstand the local conditions of drought risk and so provide for subsistence needs as well as to produce some income. The more humid the local environment, the greater the emphasis has been on cropping, while drier conditions have favoured stock-raising. There are four general types of dry farming systems in the Sertão: semi-extensive stock-raising, mixed farming, highland cropping, and semi-intensive cattle raising. The first three are traditional land use systems while semi-intensive cattle raising has arisen in the last two decades.

The zone of semi-extensive stock-raising covers nearly one half of the area of the Semi-Arid Zone where about a third of the Sertanejo population is encountered.[1] This type of ranching is the main pursuit in the drier parts of the Sertão where rainfall is very irregular, concentrated in two or three months of the year and is less than 600 mm annually. In such places soils are shallow, rocky and generally of poor fertility.

Goat and sheep raising form the subsistence base and about three-quarters of these, as well as all cattle, are sold. Cropping activity has always been of limited proportions. Modest areas of beans, cotton, maize, pumpkins and watermelons are planted in bottomlands but, with the exception of cotton, cropping is an uncertain activity and the chances of taking in a harvest are usually slim in most years. Even cotton harvests vary from year to year, depending on rainfall, so that the real money-maker remains stock-raising.

Mixed farming of stock-raising associated with rain-fed cropping is practised in about a 13% of the area of the Sertão, where almost a quarter of the population resides. In these places annual rainfall is between 600 and 800 mm, is not so irregular as in extensive stock-raising zones and is concentrated in three to four months of the year. Soils can be of considerable fertility but the threat of drought always hangs over farming activities.

Large-scale cotton cropping is practised in nearly ideal climatic conditions for the arboreal type and in such zones even part of the interfluvial lands can be used for growing cotton. Beans, maize, pumpkins and watermelons are planted in association with cotton in its first year of growth while it is still immature.

Stock-raising is intimately associated with cropping and is of equal importance for farmers. Crop residues left in the fields after harvest serve as valuable dry season pasture for cattle. Fields are rotated in such a way as to always open up new areas of bush which then becomes pasture after a few years of cropping. Old fallows revert to bush and are then exploited as open range grazing areas. In the general survey, a trend was detected for large and medium land-owners to have given more emphasis in recent years to semi-intensive cattle raising. This occurred in response to prolonged drought and to blight and market difficulties in cotton cropping.

Highland cropping zones cover less than a tenth of Sertanejo lands but 22% of the population is found there. Good soils are encountered in these places and rainfall is more dispersed and regular, with precipitation being above 800 mm annually. Greater rainfall permits the planting of such long cycle crops as manioc, sisal, bananas, pineapples and a number of other fruits. The more humid areas even have sugarcane and coffee. Farms in these zones are often specialized in either cropping or improved stock-raising.

A semi-intensive type of specialized cattle raising is becoming the predominant activity in some highland areas of the Sertão, especially in Bahia State. This form of ranching covers 28% of the Sertão and about 22% of the Sertanejo population is encountered in these zones. The ranching system is based on the large-scale planting of pangola grass (Digitaria decumbens) which can only be utilized under semi-humid and humid climatic conditions much like those of the coastal zones from where it diffused. Also, as in these zones, serious socio-economic problems have arisen with the introduction of this form of ranching (Andrade, 1982; Bicalho, 1980; Henfrey, 1984; Hoefle, 1983; Melo, 1980).

The dry farming systems of the study area are mainly of the extensive stock-raising type. Mixed farming was traditionally practised in the most northerly part of the study area but a modern trend exists among large land-owners there to switch over to semi-intensive cattle raising, much as is happening in other mixed farming zones of the Sertão.

TECHNOLOGICAL CHANGE IN DRY FARMING

Among dry farming activities, cattle raising has undergone more change and, in fact, the activity has been gradually intensifying in response to increased market opportunities and to the introduction of new rearing methods. This has been possible because many improved cattle raising practices were developed for semi-arid regions of North America and hence less difficulty is involved in adapting these to Sertanejo ranching. Nevertheless, many new ranching methods have only been adopted in a limited way due to problems with drought and lack of capital.

Rain-fed cropping, on the other hand, has changed very slowly. One serious problem is low market prices which do not permit the use of expensive new methods. Furthemore, most modern cropping methods were developed for well watered cropping conditions and for farms where large areas are planted. These are suitable for irrigation in the Sertão but not for rain-fed cropping under semi-arid conditions where most farmers have small areas of crop lands and modest amounts of capital. Finally, drought makes rain-fed cropping so uncertain that farmers are not willing to increased risk even more by using expensive production schemes.

Changing Stock-Raising Methods

Historically, as the Sertão has become more settled, population pressure, declining farm size and new cash needs have caused ranching gradually to intensify and to shift away from the extensive system of the colonial period. During the present century cattle raising in most of the zone has shifted to a semi-extensive system associated with rain-fed cropping. New pastures and fodders have been planted, barbed wire fencing is being used to close off the range, reservoirs have been constructed, more productive breeds have been introduced, and the treatment of diseases has improved. In some highland areas, cattle raising has even become a semi-intensive type. The rearing of other types of livestock, such as goats, sheep, pigs and poultry, has remained extensive in nature.

Ranchers were able to intensify cattle raising methods because demand for beef and cattle prices have risen faster than for other types of livestock. Hence, while some of the new rearing methods have been adopted in order to make cattle raising less vulnerable to drought, most have been adopted in order to raise productivity and so earn more income.

In most areas of the Sertão, as farm size has decreased and cropping activity has increased, livestock were displaced from wet season pastures located in bottomlands. These have been fenced for cropping and planted pasture. During the dry season the animals graze freely on the unfenced interfluvial lands, where the rancher or a cowhand will periodically check their condition. After the harvest the livestock come off the range and enter the fields to graze on crop residues and in pasture areas.

Despite decreasing property size, ranches of the Sertão still have plentiful amounts of interfluvial lands but little pasture is available on the range during the dry season. The scarce resource during this half of the year is bottomland pasture and this explains why farmers have focussed most of their attention on intensifying the grazing potential of these lands.

A number of bottomland planted pasture grasses and fodders, such as capim de planta (Panicum purpurascens), guinea grass (Panicum maximum), grama grass (Cynodon dactylon), capim milão (Panicum verticillatum) and sugarcane (Saccharum officinarum) were introduced in the 1950s. They have been increasingly accepted by local stock-raisers, so that at the time of the field research 41% had at least small areas of these pastures. In the last decade other types of improved pasture have been introduced and are diffusing rapidly, with 45% of the 64 interviewed ranchers utilizing them. The most important are elephant grass (Pennisetum purpurum), capim braquiara (unidentified) and pangola grass (Digitaria decumbens).

An important interfluvial fodder is palma forrageira (Opuntia ficus indica), which was introduced into the Northeast in the 1940s (Andrade, 1960). Of the ranchers interviewed, 58% had at least a modest area of cactus fodder. Buffal grass (Pennisetum ciliare) is another interfluvial pasture which has been introduced in the last few years. It shows great promise because it does not require as much work to plant and maintain as does palma.

As yet only modest areas of planted pasture and fodders have been established so that they are used only in the dry season when the livestock come off the range and even then they are often used as a last resort when drought threatens. The size of planted pasture is still too small to be of help in prolonged droughts. On the farms visited in the 1977-79, the pasture area had already dropped by 55% from that of 1974, the year before the drought began.

With greater market integration, processed cereal and cotton seed cake feeds have become available in the Sertão, but they are expensive and are only used on a large scale by a few wealthy ranchers during the dry season. Nevertheless, stock-raisers may use them for a limited number of prize animals in severe drought years, so that 45% of the interviewed ranchers were using purchased fodders at the time of the research.

Also ranchers who face pasture shortage resort to renting crop residue land and native pasture from farmers without livestock, or in nearby areas where rainfall was better in a given year. In the northern part of the study area, where stock-raising is associated with cropping, 47% of the ranchers interviewed resort to this practice, while in the south, where cropping activity is limited, the alternatives are only either using bush fodders or buying maize and cotton seed cake. Even in the north rented pasture does not meet demand in dry years.

Barbed wire <u>fencing</u> is usually introduced in conjunction with improved pasture. In the past, pole and wicker fencing was utilized to enclose only cropping areas. Ranchers find barbed wire more practical to erect over larger areas of pasture. It also lasts up to fifty years under the semi-arid conditions of the Sertão, which is five times longer than fencing made from materials collected from the bush. However, barbed wire is expensive and only medium and large ranchers use it on a larger scale, while small stock-raisers continue to use pole and wicker fencing to enclose modest areas of pasture.

Consequently, 37% of the ranchers interviewed fence pasture with barbed wire but only 10% have fenced the greater part of their properties.

Another improvement in order to make stock-raising less susceptible to drought and more productive is the construction of small reservoirs. Although only medium and large ranchers can afford to build barrages large enough to withstand a prolonged drought and to irrigate pasture, many small stock-raisers have built modest sized reservoirs. About one half of the interviewed ranchers have reservoir of some type.

The first new breeds of zebu cattle (*Bos indicus*) were introduced into the Semi-Arid Zone in the 1940s. However, most ranchers only began to improve their whole herd in the late 1960s when improved types of zebus and mixed zebu/European stocks became available in greater numbers. Newer breeds weigh from 150 to 200 kilos when reared under the current semi-extensive system and they reach this size by four years of age. The traditional breed of cattle, called *pé-duros*, attained a mere 105 kilos weight only after six to seven years of growth.

Given the extensive nature of stock-raising in the past - and even that of the present system - the treatment of livestock disease has always been restricted. During most of the year the treatment of an animal depends on the possibility of catching it on the range of dense thorn bushes. In the past, about the only treatment cattle received, besides resort to curing prayers, was the application of creosote on festering wounds.

On the other hand, contagious disease was rarer than today. In addition, the climate and the extensive nature of cattle raising means that, animal disease is not such a problem as it is elsewhere. Of the diseases that affect livestock, rabies has only become a problem in the last five years. Foot-and-mouth disease seems to have been present since the 1930s but it only strikes in the rainiest of years. Of the ranchers interviewed, 70% now use rabies vaccine for cattle while 74% use foot-and-mouth vaccine. Other animal diseases, for which there is a cure or preventive vaccine, do not pose such a problem as these two, and are rarely treated.

The Limits to Intensification in Rain-Fed Cropping

In terms of preventing harvest failure, raising productivity and increasing income, rain-fed cropping has been little altered by the technical innovations that have become available in recent years. Tractors are used by some farmers and pesticides by a fair number but many other innovations have not been adopted because they are simply inappropriate for the environmental and socio-economic conditions of the Sertão.

New cropping methods are used mainly for cash crops and in more humid areas where harvests are less prone to failure. The use of pesticides, fertilizers, selected seed and tractors is, therefore, restricted to medium and large cotton growers, who can also use them for staple crops when these are grown in association with cotton.

The use of tractors for land preparation in dry farming is limited by the small scale of cropping on most Sertanejo farms, by climatic risk and by the high cost of tractor rental. Only bottomlands are appropriate for ploughing with tractors and most farms have modest amounts of such land. This is due to the long narrow property form of Sertanejo farms.

In the northern part of the study area only one of the farmers interviewed uses a tractor and another uses animal traction. In the south not a single farmer interviewed uses a tractor in rain-fed cropping, while 8% use animal traction. In the counties of the general survey about half of the farmers of highland cropping zones were estimated to prepare land with tractors, 10-35% use them in mixed farming zones, while few, if any, use them in drier stock-raising areas. Animal traction is most common in highland cropping and mixed farming zones, being used by 30-85% of the farmers in such places.

Chemical fertilizers and even manure are rarely utilized in rain-fed cropping and their use was found to be restricted to one or another cash crop in humid highland zones. Not a single interviewed farmer of the study area uses fertilizers of any type. Besides the cost involved, the application of chemical fertilizers in most parts of the Sertão is not practical. Sanders & Hollanda (1977) have shown that they do not function properly in the absence of a relatively high, steady degree of soil humidity during the crop cycle which rarely occurs in the Sertão. A sudden thundershower can also wash fertilizer away and this is the most common form of precipitation in the zone.

Agronomists seem to have reached a similar conclusion so that the technical packages used by rural extension agents do not recommend the use of chemical fertilizers for rain-fed cropping (EMBRAPA, 1974, 1976). Instead it suggests fertilizing with animal manure. However, given the extensive nature of stock-raising, it is impractical to collect the twenty tons of manure per hectare that is recommended. For the greater part of the year most of the livestock are free to roam on the range and so their manure is scattered over the bushlands, which makes it extremely difficult to collect. Some livestock graze for a few months of the year in the fields but this natural form of manuring alone is not enough to restore soil fertility.

This situation is further worsened by diminishing farm size. As farms have decreased in size, bottomland fallow periods have been reduced to one or two years and farmers complain of decreasing returns. Hence, the dilemma of Sertanejo dry farming is not just one of droughts reducing harvest size but also of declining soil fertility.

Pesticides are the innovation that is most widespread but even for these the drier the zone, the less inclined farmers are to use them. In the general survey counties pesticides were estimated to be used on cotton, beans and maize by 80% to 100% of the farmers in highland cropping zones while this figure drops to 40-60% in the mixed farming zones of Ceará and Paraíba States, and to less than 25% of farmers in dry zones. The farmers of the study area show similar behaviour. In the southern part of the area, where dry farming harvests are uncertain, less than 20% of the interviewed farmers use pesticides on their principal crops. In the north, while the use of pesticides on beans and maize is low, 46% of the farmers use them on cotton (Table 6).

Table 6. Use of Pesticides in Rain-Fed Cropping in the Study Area.

Sector and Crop	Farmers Planting Crop	Farmers Using Pesticides	
		n	%
NORTH			
Beans & Maize	14	1	7
Cotton	11	5	46
Rice	14	0	0
Others	3-14	0	0
SOUTH			
Beans & Maize	26	5	19
Cotton	26	3	12
Others	7-26	0	0

Source of Data: Field Research.

There are, thus, a number of reasons why rain-fed cropping has shown little technical change. Many of the new techniques are not environmentally suited to the zone. They also do not significantly increase productivity nor reduce drought risk. More importantly, crop prices are not high enough to enable the use of the costly new industrial inputs which have become available in the Sertão in recent decades.

Cattle raising has been consistently more profitable than dry farming and a number of new methods which increase productivity have been adopted. Furthermore, stock-raising is naturally less vulnerable to drought and is now less adeversely affected during years of low rainfall. Nevertheless, considerable losses still occur during prolonged droughts which, in turn, slows the pace of technical innovation.

THE IMPACT OF DROUGHT

Climatic risk can act as a stimulus to change by encouraging farmers to adopt new methods which could limit drought losses. On the other hand, drought can act as a barrier to change by making an already risky profession more so. Overall risk can be raised to the point where farmers are not willing to use expensive new inputs. Drought works in both manners in the Sertão. The risk of drought loss helped stimulate change in cattle ranching but prolonged drought slows the pace of change. Drought is essentially negative for rain-fed cropping.

Therefore, neither the old extensive nor the current semi-extensive cattle raising system provides enough water and pasture for livestock during drought. Consequentely, herd size has fluctuated over time, increasing gradually, faster in more favourable decades and slower in decades of drought. A number of severe droughts took place during the 1950s which limited the increase in the size of the

Sertanejo cattle herd to only 1% during this decade. During the favourable 1960s the increase was faster, being 27% (Fundação IBGE, 1955b, 1966b, 1975b).

The nearly continuous drought from 1975 to 1983 devastated stock-raising. By the late 1970s cattle herds had been reduced by about a third and goats and sheep by half in the study area (Table 7). In 1983, it was learned that almost all the cattle, sheep and even goats have perished or have been sold in the drier southern part of the area.

Table 7. Change in Average Herd Size for Ranchers of the Study Area.

Sector	Cattle				Goats and Sheep			
	n	1965-74	1977-79	change	n	1965-74	1977-79	change
		number	number	%		number	number	%
North	20	76	50	-34	24	371	154	-59
South	38	159	100	-37	40	671	376	-44

Source of Data: Field Research.

The severe effect of drought on rain-fed cropping can be seen in the sharp variation in area planted, in production and in productivity for different crops on the farms in the study area between 1976 and 1979 (Tables 8 & 9). During this period, 1976 and 1977 were drought years, 1978 was a fair year for rainfall and 1979 was a poor one.

In the southern sector, the area of arboreal cotton decreased by nearly two-thirds between 1976 and 1978 as individual cotton plants gradually succumbed to drought. Rainfall was fair in 1978 and the harvest was better and productivity higher. The climate of the north is not as dry so that the area planted in cotton and the harvests of 1978 and 1979 were not so different.

Table 8. Average Annual Area Planted, Production and Productivity per Farmer in the North of the Study Area.

Crop	1978				1979			
	n	ha	kg	kg/ha	n	ha	kg	kg/ha
Beans	13	0.9	703	781	15	1.3	474	365
Cotton	12	19.6	1438	73	10	19.0	1424	75
Maize	13	1.1	440	400	13	2.3	711	309
Rice	5	1.1	913	830	6	1.3	108	83

Source of Data: Field Research.

Table 9. Average Annual Area Planted, Production and Productivity per Farmer in the South of the Study Area.

Crop	1976				1977				1978			
	n	ha	kg	kg/ha	n	ha	kg	kg/ha	n	ha	kg	kg/ha
Beans	18	0.8	180	225	30	0.7	87	124	12	0.5	135	270
Cotton	11	5.0	1328	266	20	3.2	1277	399	6	3.1	2217	715
Maize	14	0.7	122	174	27	1.0	144	144	13	1.7	864	508

Source of Data: Field Research.

Where variation in production and productivity is particularly marked between drought and non-drought years is in staple cropping. Throughout the study area, production and productivity of beans, maize and rice for 1976, 1977 and 1979 were usually much lower than that of 1978. More importantly a number of farmers experienced complete harvest failure during dry years. In 1976, 36% lost all of their maize and 31% all of their beans. In 1977, 40% did not harvest any maize nor 37% any beans. In 1979, 25% lost their harvest of beans, 29% of maize and 25% of rice. In 1978 no one lost their harvest.

FARM PRICES AND LOW INCOME

Urban-industrial biased pricing policies also have had an adverse effect on Sertanejo dry farming. The policies discriminate against staple cropping, give a modest boost to cattle rearing, promote cash cropping and usually leave fruit and vegetable cropping to market forces.

During the period 1945-1960 the price of most farm products rose in response to the increased demand of the growing urban markets of Brazil (Patrick, 1972). After 1960, the urban-industrial biased pricing policies entered into force as a succession of governments tried to control run-away inflation. These policies have only been selectively relaxed for staples during the last six years but price levels have still not recuperated from decades of control. Moreover, prices on the international market for traditional cash crops of the Sertão have also been poor for decades (Tables 10 & 11). Thus, given a situation of high drought risk and low prices it is not surprising that rain-fed cropping has experienced slow technical change, while cattle raising has gradually intensified and irrigation cropping has experienced rapid transformation.

Table 10. Price Index for the Main Farm Products of the Sertão for the Period 1948-1969.

Product	Price Index (1955 = 100)			Price Change (%)	
	1948/50	1959/61	1967/69	48/50-59/61	59/61-67/69
STAPLES					
beans	93.1	125.5	100.6	34.8	-19.8
maize	104.0	119.7	94.9	15.1	-20.7
rice	114.7	115.6	105.6	0.8	-8.7
sweet potatoes	96.1	101.5	100.1	5.6	-1.4
CASH CROPS					
cotton	129.2	129.3	88.1	0.1	-31.9
sisal	275.3	149.8	77.5	-45.6	-48.3
IRRIGATED VEGETABLES					
onions	157.7	86.6	125.7	-45.6	45.2
tomatoes	84.9	161.6	487.3	90.3	201.5
LIVESTOCK					
beef	74.4	117.5	133.7	57.9	13.8
dairy products	118.8	116.3	122.5	-2.1	5.3
goat meat	78.9	122.3	124.6	55.0	1.9
mutton	77.9	121.1	123.2	55.5	1.7

Source of Data: Patrick (1972).

Table 11. Price Index for the Main Products of the Sertão for the Period 1969-1982 (Undeflated Cr$, 1969 = 1.0).

Product	1969	1974	1979	1982
STAPLES				
beans	1.0	3.2	16.5	100.9
maize	1.0	3.5	18.5	116.6
rice	1.0	3.7	20.5	131.9
CASH CROPS				
cotton	1.0	4.6	22.8	138.5
LIVESTOCK				
beef	1.0	5.1	35.2	142.8
dairy products	1.0	3.7	18.5	129.8

Source of Data: Fundação Getúlio Vargas (1978, 1983).

In general, ranching requires more land to support a farmer and his family than does cropping (Morgan & Munton, 1971; Symons, 1972). Consequently, income per hectare for stock-raising in the Sertão is usually low. However, operating costs per hectare are also low, even when using salaried cowhands, so that all forms of Sertanejo stock-raising are reasonably profitable (Table 12). As Sertanejo farms possess much more pasture land than crop lands, more overall income can be earned in livestock rearing. This is true even for semi-extensive cattle raising where ten hectares of bush lands are needed per steer as well as for the semi-intensive system where three hectares per steer are needed.

In the study area, a few large ranchers use a semi-intensive system and salaried cowhands. Some medium and most large stock-raisers use semi-extensive techniques and employ waged or product-sharing ranch hands. Most of the other stock-raisers have small herds so that they use semi-extensive rearing methods and rely on family labour.

The semi-intensive system is more profitable than the various forms of semi-extensive cattle raising but to use it a rancher must assume greater risk in the form of higher operating costs. These costs rise sharply in years with little rainfall, like 1979. Furthermore, a rancher must have the means to invest in costly fixed capital items such as large reservoirs, irrigation equipment, fodder cutting machinerty, etc. At any rate, all forms of stock-raising are profitable enough to have permitted a gradual improvement in methods whereas the opposite has been the case for rain-fed cropping.

Table 12. Average Profit per Hectare for Ranchers in the Study Area (US$)(a).

Income and Costs(b)	Cattle				Goats and Sheep	
	semi-intensive	semi-extensive			extensive	
	wage labour	wage labour	sharing	family labour	sharing	family labour
1976						
Cash costs	n.a.	0.7	0.9	0.3	0.4	0
Gross income	n.a.	1.3	0.7	0.8	1.6	0.5
Net income	n.a.	0.6	-0.2	0.5	1.2	0.5
1977						
Cash costs	n.a.	0.8	1.0	0.3	0.4	0
Gross income	n.a.	1.4	1.2	0.6	1.7	0.7
Net income	n.a.	0.6	0.2	0.3	1.3	0.7
1978						
Cash costs	1.9	0.7	1.1	0.4	0.3	0
Gross income	22.7	1.9	2.2	3.1	1.3	0.8
Net Income	20.8	1.2	1.1	2.7	1.0	0.8
1979						
Cash costs	4.6	-	-	0.8	0.2	0
Gross income	21.6	-	-	4.5	0.7	0.5
Net income	17.0	-	-	3.7	0.5	0.5

Source of Data: Field Research.

(a) Calculated for total ranch size. Sample size: 1976 (n = 28), 1977 (n = 30), 1978 (n = 33) & 1979 (n = 22).

(b) Operating costs only. Costs include cowhands's wages and shared part, but exclude use of own pasture, work of a rancher supervising cowhands or his and his family's work.

High climatic risk and low farm prices means that the adoption of many possible cropping innovations does not make economic sense. Profit margins simply do not permit the use of more intensive systems for most dry farming crops. No farmers were encountered who used a system resembling a capital-intensive one. Some large and medium farmers use as an intermediate type in which some pesticides are used, animal drawn traction is employed instead of tractors, and about half of the labour employed is waged while the other half is family labour. The modest capital resources of most other farmers and the limited perspectives for income encourage the use of a labour-intensive technology where no industrial inputs of any kind are used, only manual tools are employed and all work is undertaken by family members.

Comparing costs to the income which farmers of the study area earned in different years, one sees why less costly cropping systems are used (Table 13). With the exception of 1976, if a capital-intensive or intermediate system had been used during years of low rainfall profit margins would have been lower or money would have been lost. Even the production and income obtained in a fair year like 1978 often does not justify the use of more intensive systems. At best, an intermediate system could be used in the North when farmers think a rainy year is in the offing. Otherwise, in drought years industrial inputs do not raise productivity nor do anything to save the harvest.

Given the difficulties facing rain-fed cropping in the Sertão many farmers have been reducing their cropping areas and concentrating on stock-raising. While it can be argued that the ecological conditions of the Sertão in fact call for such a ranching focus, the price distortion of national farm policy is also responsible for this trend. Cropping is caught in a vicious circle whereby it cannot be intensified so that many farmers find it more advantageous to turn fields into pasture.

Table 13. Average Profit per Hectare for Farmers Exploiting Rain-Fed Cropping in the Study Area (US$)(a).

Crop and Sector	Costs(b)			Gross Income			Net Profit		
	System(c)			System(c)			System(c)		
	1	2	3	1	2	3	1	2	3
NORTH									
1978									
Beans & Maize	224	67	2	n.a.	248	248	n.a.	181	246
Cotton	124	69	1	n.a.	68	25	n.a.	-1	24
Rice	455	117	13	n.a.	141	285	n.a.	24	272
1979									
Beans & Maize	194	64	2	n.a.	102	58	n.a.	38	56
Cotton	141	82	1	n.a.	18	5	n.a.	-64	4
Rice	464	103	11	n.a.	123	155	n.a.	20	144
SOUTH									
1976									
Beans & Maize	224	53	2	n.a.	125	67	n.a.	72	65
Cotton	99	53	1	n.a.	399	119	n.a.	344	118
1977									
Beans & Maize	158	52	2	n.a.	60	43	n.a.	8	41
Cotton	97	51	1	n.a.	114	143	n.a.	63	142
1978									
Beans & Maize	224	67	2	n.a.	91	93	n.a.	24	91
Cotton	124	69	1	n.a.	194	205	n.a.	125	204

Source of Data: Field Research.

(a) Sample size: North 1978 (n = 13) & 1979 (n = 15); South 1976 (n = 18), 1977 (n = 30) & 1978 (n = 13).

(b) Cash operating costs only. Work of farmer supervising labourers or his and his family's work is not counted as a cash cost. Share-croppers part is treated as a cost.

(c) System 1 is a hypothetical capital-intensive case based on EMBRAPA (1975-1976). System 2 is an intermediate technology type with half of the labour used being waged. System 3 is a labour-intensive type case which relies entirely on family labour.

This can be seen in the relative importance of the income generated from ranching on farms of all size (Table 14). Even in fair years for rainfall, like 1978, large and medium farmers in both the north and the south of the study area receive the greater part of their income from ranching nowadays. Smallholders too receive a substantial portion of income from stock-raising rather than from cropping. For them only cotton is a money earner while the other crops are planted mainly for subsistence.

Table 14. Average Net Income according to Activity and Farm Size in the Study Area (US$).

Sector	Small (<100 ha)		Medium (100-500 ha)		Large (>500 ha)	
	Ranching	Cropping	Ranching	Cropping	Ranching	Cropping
NORTH						
1978	1579	803	2825	1211	5212	-681
1979	1288	189	2221	879	7161	-2719
SOUTH						
1976	881	145	787	374	5064	462
1977	509	202	1261	751	5681	344
1978	662	305	1778	1065	6794	722

Source of Data: Field Research.

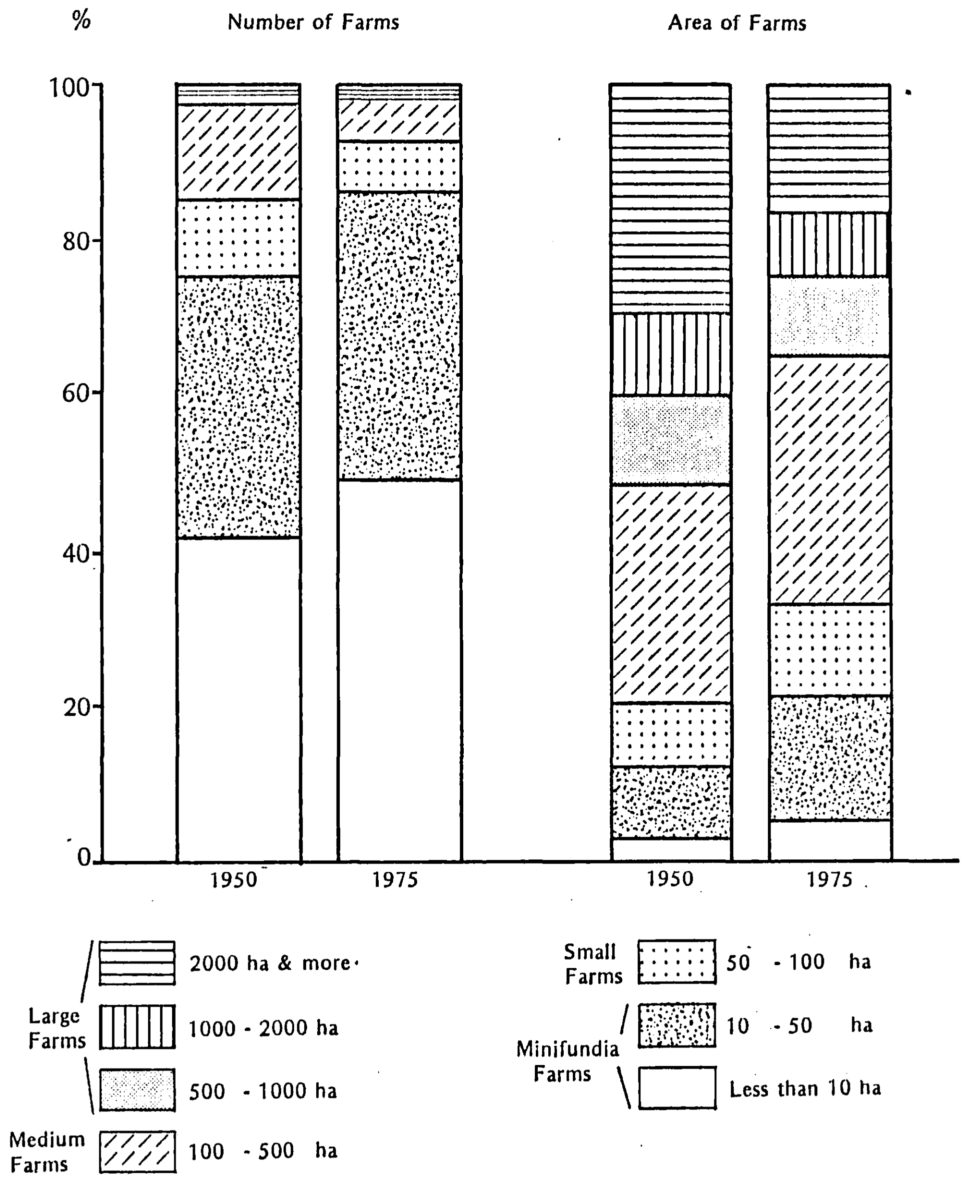
Nevertheless, while more income can be made by exploiting stock-raising, ranching is naturally a more land extensive activity than is cropping. This, in turn, presents a serious dilemma for Sertanejo society. In order to earn enough income from stock-raising, farms must be maintained intact but this means that land will not be available for all a land-owner's children nor for former crop workers.

DECLINING FARM SIZE

The land inheritance system of equal distribution of property amoung numerous heirs has led to a pattern of rapidly declining farm size throughout most of the Sertão. In such a context, slow technological change, therefore, has serious consequences. If production methods could be intensified, farmers would still be able to earn a satifactory living from diminished land holdings. If they cannot do this quickly enough their situation worsens because many innovations which could intensify production are not within the reach of small farmers. This latter situation is more common for farmers of the Sertão. The prospects for increasing rural income as well as for fully employing the labour force are dim. Farm size continues to fall, less job opportunity is available and intense emigration has been the result.

In the past, the ranches of the Sertão were immense and some cattle empires covered thousands of square kilometres, stretching across states (Andrade, 1973; Pierson, 1972). However, by this century the erosive force of equal inheritance had drastically diminished their size. Some elderly ranchers who own up to 30,000 hectares can still be encountered in places but they are so rare today that it is incorrect to still characterize farm holding in the Sertão as an opposition of latifundias and minifundias. Dividing a holding between the heirs of families that can have from six to twelve children, rapidly reduces large farms to small ones. The size of farms has continued to decline relentlessly so that by modern times many of them barely enable a family to make a decent living.

In most places a minifundia farm is that with less than 50 hectares, a small farm 50-100 hectares, a medium farm 100-500 hectares and a large farm has more than 500 hectares.[2] From 1950 to 1975 small and minifundia farms increased from 86% to 93% of the total number of Sertanejo farms and their proportion of the total area in farms rose from 20% to 33% (Figure 5). During this period, the proportion of farms that are medium sized decreased from 11% to 6% and the total farm land occupied by this type of farm increased slightly from 28% to 32%. Similarly, the proportion of farms that are large fell from 3% to 1% and the area they occupy also decreased significantly, from 52% in 1950 to 35% in 1975. Hence, Sertanejo farm size is decreasing and while disparities in land ownership still persist the predominance of large farms is on the wane.



Source of Data: Fundação IBGE (1955b, 1979).

Figure 5. Change in the Size of Farms of the Sertão.

Declining farm size, therefore, is proceeding rapidly throughout the Sertão and increasing population pressure is keenly felt on smaller holdings but this has not caused a significant intensification in dry farming methods in the way that Boserup (1966) postulates. As Bayliss-Smith (1982), Sahlins (1974) and Sanders (1972) demonstrate elsewhere with respect to Boserup's ideas, important environmental and socio-economic barriers exist which can prevent this. Questions of cash cropping and rural income are just as important as subsistence production in peasant farming today and most peasants simply do not have access to the resources needed to intensify their farming system.

This is clearly seen in the process of 'involution' which took place in the Sertão. As farms size declined in the absence of technical change, cropping area expanded into marginal lands where the risk of drought is greater. Between 1950 and 1975, new land was brought into cropping at an average rate of increase of 4.7% per year and this was well above the rate of population increase, 1.8% per annum, during roughly the same period (Fundação IBGE, 1955a, 1955b, 1979, 1981). Much of this expansion occurred during the rainy 1960s but it was undertaken in an attempt to compensate for falling crop prices rather than in response to population pressure, and the increased area still did not generate enough income to satisfy the growing consumer aspirations of Sertanejo farmers.

So, rather than attempting the frustrating task of making a living from farming, many Sertanejos instead choose to leave the countryside. First, landless peasants and, then, children of small and medium property holders have moved to the towns and cities of the Sertão and, lacking enough work there, they have had to emigrate from the zone altogether. This started in the 1950s, gathered force during the 1960s and became more accelerated after 1974 with the onset of one of the worst droughts in Sertanejo history.

EMPLOYMENT OPPORTUNITY AND EMIGRATION

Between 1950 and 1980 the relatively small increase of 38% in the number of persons employed in agriculture and the decline in the proportion of farm workers in the total work force from 72% to 52% reflects the depressed state of farming as well as its declining prestige (Table 15). Monetarization of the economy offered new opportunity for employment outside of the farm sector but unfortunately not at fast enough of a rate. While the number of Sertanejos employed in light industry rose by 379% from 1950 to 1980, in commerce by 204% and in services by 271%, the number of unemployed also rose by 184% at a time when the overall work force increased by only 92%. Moreover, the unemployed increased their proportion of the total work force from 16% to 24% of the total during this period.

Table 15. Change in the Proportion of the Sertanejo Work Force Employed by Sector.

Sector	1950 number	1950 %	1980 number	1980 %	Percentage Change 1950/80
Agriculture	1 408 091	71.7	1 936 507	51.5	37.5
Light Industry	69 677	3.5	333 919	8.9	379.2
Commerce	66 022	3.4	200 462	5.3	203.6
Services	107 778	5.5	399 897	10.7	271.1
Unemployed	313 047	15.9	888 701	23.6	183.9
Total	1 964 615	100.0	3 759 486	100.0	91.6

Source of Data: Fundação IBGE (1955a, 1983).

The depressed economy has, in turn, led a large part of the Sertanejo population to emigrate. The droughts effect the incidence of emigration but the rate of population increase is below the national level in periods of both plentiful and sparse rainfall (Table 16). The net rate of population growth in the Sertão during the 1950s was the lowest of the period studied because of severe drought and because growth of jobs outside agriculture only came after 1960. The 1960s were a period climatically favourable for dry farming and the rate of population increase was 2.6%, but which was still below the national rate of 2.9%. The 1970s saw such an expansion in other types of jobs, but this did not counterbalance the negative effects of the depressed state of farming and the severe droughts of the period so that the rate of increase was a mere 1.5% per annum.

Table 16. Annual Rate of Population Growth from 1950 to 1980.

Region	1950-1960	1960-1970	1970-1980	1950-1980
Sertão	1.2	2.6	1.5	1.8
Northeast	2.2	2.5	2.1	2.3
Brazil	3.2	2.9	2.5	2.9

Source of Data: Fundação IBGE (1955a, 1962, 1972, 1981).

In sharp contrast to the Sertão the period after 1950 was one when the industrial Southeast of Brazil boomed. Sertanejos in large numbers were drawn there to find work and to what they considered to be a much superior city lifestyle. Even during the late 1970s and early 1980s when the national economy has grown slowly and when jobs are increasingly difficult to find in the Southeast, the situation of drought and unemployment at home is so desperate that many Sertanejos still go to the Southeast. Emigrants may wait for a relative who lives there to line up a job for them before they go, but many young men emigrate as soon as they reach eighteen years of age and receive their identification card. Indicative of this is the fact that 28% of the working children of interviewed residents of the study area live outside the Sertão.

While much of this whole situation is caused by local factors, state and federal government must receive a good deal of the blame. Urban-industrial bias and unbalanced development policy have brought few benefits for what is a peripheral zone of a peripheral region. The plight of the Sertão only comes to national attention when severe drought strikes and media coverage brings scenes of hunger and suffering into living rooms across the country. However, the usual response, besides the resort to short-term work projects, is to pour more money into the so-called projects of integrated development. These merely concentrate resources in a few places, usually in show case irrigation projects, while the rest of the region languishes.

Irrigation will be shown to be an important element for overcoming the rural problems of the Sertão but it is not a panacea for all the ills. Dry farming throughout the zone will have to be improved and this calls for a much more ambitious programme of government aid than that represented by efforts to date. Institutional barriers to credit for smallholders will have to be removed. Government banks and the extension service should attend to the needs of the whole community and not to those of the privileged few. More rapid technical innovation is necessary and this means distributing infrastructural improvements uniformly throughout the Sertão. Above all, farm prices must rise faster than inflation in order to make up for lost ground or they should at least be allowed to keep pace with inflation and this means that the government will have to cease sacrificing the rural zone in favour of the large cities.

5. THE RISE OF IRRIGATION IN THE NORTHEAST

In contrast to dry farming of the Sertão, irrigation has experienced rapid technical change. Farmers find irrigation highly attractive because it dramatically raises their incomes as well as provides the means for capital accumulation which enables them to undertake further technical change.

For many of the same reasons, government efforts to promote rural development in the Semi-Arid Zone have long focussed on irrigation. Indeed, the state and federal governments have played an important role in the expansion of the activity. Indirect assistance in the form of infrastructural improvement, the provision of bank loans and technical assistance to private-sector farmers will be shown to have been far more effective for promoting the development of irrigation than has the more recent direct intervention of the government. Moreover, contrary to what many government development planners think, irrigation existed in the Sertão long before government attempts to promote the activity.

There is some historical reference to irrigation being present in the Northeast for at least two hundred years. Gravity irrigation of sugarcane was practised on some tributaries of the upper-middle São Francisco river in the early 1800s (Pierson, 1972). Irrigation in the Brumado valley of Bahia state is reported from the same period (DNOCS, n.d.). Informants along the lower Jaguaribe River say that their use of windmills and other devices to lift water to their crops is more than a hundred years old. Finally, the occasional use of irrigation by carrying water in buckets and leather sacks to parched crops when the latter showed signs of failure is hard to date but must be as old as agriculture in the Semi-Arid Zone. On seasonal rivers, rice planted on the river edge is often saved by such action. The practice of this occasional irrigation is the base from which full-fledged irrigation developed.

Although there are examples of irrigation being an old practice in parts of the Sertão, this does not mean that it was common throughout the region. On the contrary, irrigation was restricted to small crop areas that usually only supplied the needs of the local population. From a historical perspective the activity did not diffuse gradually over the centuries but rather it spread quickly and cumulatively in recent decades. Irrigation began to expand after 1950 and only in the last fifteen years has it diffused throughout the region. Nowadays the size of fields varies from small areas devoted to a farmer's basic needs to large fields producing cash crops for the national market.

On the other hand, while irrigation is encountered throughout the Sertão today, it is only important in a few localities, such as along the São Francisco River (the study area) and lower Jaguaribe River (Ceará) and in the Chapada da Diamantina (Bahia). These areas have become specialized in irrigation and new commercial crops have been introduced. In such places, irrigated area and production have increased rapidly and technological innovations have been accepted readily, resulting in a spiral of agricultural transformation.

Whether irrigation flourishes or not depends on the existence of markets for the increased production and on the infrastructural improvements that are necessary to sustain irrigation and market the produce. This implies that undertaking of extensive public works which, in turn, depend on the involvement of federal and state government. Historically, the government has usually only been spurred into action by catastrophic drought.

FIRST GOVERNMENT EFFORTS TO PROMOTE IRRIGATION

With the exception of the failed attempt to practise irrigation on the Cedro reservoir project in the early 1900s, concrete action on the part of the government was not undertaken until the 1930s. As usual, such action was taken in response to a disastrous drought, that of 1930-32. Where irrigation did not exist, attempts were made to introduce it and where it did, its expansion was stimulated. Government policy to promote irrigation finally left the domain of ideas to become a reality, although progress was made only with painstaking slowness.

Irrigation policy for the Northeast focussed on the Semi-Arid Zone. The objectives were to increase agricultural production, to raise farmer income and to create local markets. The programme was to follow two lines of action. One was the installation of experimental irrigation farms and the other consisted of a public cooperation scheme to coordinate measures for promoting the spread of private-sector irrigation.

In the early 1930s, the first public irrigation areas were established and administered by IFOCS in Joaquim Tavora (Ceará), Lima Campos (Ceará), Santo Antonio do Russas (Ceará), Itans (Rio Grande do Norte), São Gonçalo (Paraíba) and São Francisco (Pernambuco) (Hall, 1978). However, only in 1939 did the government pass a law that was to begin more active work in irrigation. Full-fledged experimental farms were to be established and irrigation was to be introduced and expanded on private farms through the action of rural extention agents (Zarur, 1946).

The creating of experimental farms was a continuation of the earlier policy of establishing public irrigated areas. The existing areas were expanded and new ones created. All together thirteen experimental farms were set up in the Sertão. The new ones were: Crateús (Ceará), Cruzeta (Rio Grande do Norte), Pau dos Ferros (Rio Grande do Norte), Bom Jesus da Lapa (Bahia), Jacuici (Bahia), Juazeiro (Bahia) and Santo Sé (Bahia).

The experimental farms had two types of personnel: one group consisted of agronomists and clerical workers and the other was composed of rural labourers. The labourer had two distinct functions. The first was to work in the experimental fields of the project for which he was paid a salary. The second function was to till a field of his own. Even for his plot he would receive all the technical assistence and use of machinery required, paying only a low rate for the water and the petrol consumed. These expenses were discounted from the part of his production that was marketed by the farm administration.

Although this information on types of project personnel was obtained from informants and is not mentioned by Zarur (1946), he does make some reference to the creation of small irrigated plots for landless peasants and to the fact that the plots would be sold to those working them. The payment for the land was to have been made in accordance with the yearly production achieved by each farmer. However, it seems that this never came about and no one ever received title to land. Indeed, even when working on the plot that was supposed to be theirs agricultural workers never thought of themselves as being anything other than federal employees tilling government land.

In 1942, with the inception of the Itaparica project, a new feature was introduced in government actions. An agro-industrial centre was planned for the town of Itaparica (today Petrolândia) on the São Francisco River. This project was to be a joint programme executed by the federal and state government. The installation of a hydro-electric plant and a family farm colony was the centrepiece of the project. The provision of electricity would aid the process of agricultural technical change as well as stimulate the rise of rural industries which would also receive government subsidies.

The agricultural colony was organized in a co-operative system and selected families received a plot of land on which to grow vegetables and fruits. They also exploited poultry farming. After three years the families were supposed to begin paying for their land, the deed for which would be granted when they had paid in full (Zarur, 1946). This never happened and only in the last few years have public lands of the Northeast started to be turned over to the farmers who work them. At Itaparica, as elsewhere, the behaviour of the project farmers under the control of successive administrative agencies has always been that of submission to superior authorities. Thus the question of who owns the land, which is crucial for orienting peasant behaviour, is an old one on government projects.

The other principal goal of government action during the 1930s and 1940s was to expand the irrigated area and particularly to increase the number of farmers using irrigation, with special attention being given to smallholders. Plans called for the diffusion of modern irrigation technology together with the introduction of new fruits, vegetables, cereals and pastures. An infrastructure for irrigation on private farms would be implanted with public aid and an educational scheme would be carried out by agronomists to teach new irrigation methods (Zarur, 1946).

All public investment on private land was to be repaid from the profits which irrigation would make possible. Reimbursement was based on a percentage of the production, and in the end this mechanism of repayment represented a new form of rural credit. Irrigation would also confer other benefits. By assuring farm production more taxes would be collected at the county, state and national level. At the same time, the conditions of life on the farm would be improved (Zarur, 1946). These same goals and mechanisms reappear over and over again in the various plans for public irrigation which were conceived in the following decades.

In areas where some knowledge of irrigation already existed, such as on the São Francisco River, the new policy was welcomed and hundreds of farmers requested to be included in the programme. However, the programme did not get beyond initial registration, because of funding difficulties (Zarur, 1946). This author lists two other problems. The majority of farmers did not possess proper land titles which were required for inclusion in the programme. Moreover, in Zarur's opinion, large ranchers did not show much interest in irrigation because they already earned sufficient income from cattle-raising, rain-fed cropping and the rental of plots to landless peasants. Even today this last reason appears repeatly in government reports and plans. It is the classic latifundia-minifundia explanation for slow rural change. Large ranchers do not need to intensify the use of their land and smallholders do not have the means to do so. As was demonstrated in the last chapter, land distribution is no longer so polarized as it once was and we shall see later that large ranchers were, in fact, the first farmers to adopt irrigation in the 1950s.

There are other serious barriers which are seldom mentioned in the literature. In the 1930s and 1940s, the building of roads, which could enable the marketing of produce, was still in its preliminary phase. As Hodder (1973) shows, planners in the developing countries often worry more about increasing production than about whether it will get to market or whether a market actually exists. Hence Zarur, and others who came after him, usually blame problems on the farm for the failure of the irrigation programme instead of examining deficiencies in transport and marketing structure off the farm. These problems alone were enough to curtail any large-scale expansion of irrigation.

In addition, the lack of rural credit was an important barrier to the expansion of irrigation in the period prior to 1950. Some previous attempts had been made to create a bank to serve the region but the various schemes never got off the ground. Thirty years before the government established the Caixa Especial de Irrigação de Terras Cultiváveis do Nordeste Brasileiro, which was to have been oriented mainly to irrigation. It had a short period of existence, from 1920 to 1924. In 1934, the bank was ressurrected with some new objectives, such as financing public works against drought and assisting drought refugees during crisis years (Zarur, 1946). Little is documented about what happened to the bank; quite possibly it had the same fate as its predecessor after a few years of existence.

Another bank involved with rural credit at the time was the national Banco do Brasil in which a department of rural credit was created in the 1930s. However, the Banco do Brasil had little effect on the Semi-Arid Zone as few of its branches were located in the region. Also, as the bank was a national bank, it was controlled by Southeastern interests which made it difficult for loans to be applied in the Northeast. What loans that were made to farmers in the Northeast went mainly to sugarcane plantations of the coastal zone.

At any rate, the programme never left the planning stage. Only two farms in the São Francisco Valley received funds, one in Salitre

(Bahia) and the other in Massangano (Pernambuco). Between them a mere 161 hectares were being irrigated in 1942. A greater number of farmers were assisted by the São Gonçalo team in Souza county (Paraíba), who at the same time were irrigating over 1000 hectares. In both areas the farmers were charged for the investments, although in São Gonçalo they also paid a low rate for the supply of water from a public reservoir (Zarur, 1946).

The results of government efforts to promote irrigation during this period were thus meagre. At most, they resulted in the idea of irrigation being made available to a larger number of farmers but few of them actually adopted the activity. For irrigation to be practised, a good deal of infrastructural work was needed both on and off the farm. Water had to be stored, water lifting devices were needed, roads had to be improved and a consumer market had to be created.

THE EXPANSION OF IRRIGATION

The real development of irrigation in the Sertão occurred from 1950 onward. The most important stimuli to irrigation were farm loans made by the new regional government bank, the Banco do Nordeste do Brasil, and the construction of better roads linking the Sertão to the growing markets of the large cities of Brazil. The spread of irrigation that followed depended mainly on the private sector adopting the new agricultural system. The public irrigation projects that were established contributed very little to the expanding area of irrigation.

Despite the existence of other possible sources of rural credit for the Sertão, it was only in 1952, with the creation of the Banco do Nordeste, that a bank was to take a real interest in irrigation. The importance of this kind of government help in stimulating the development of irrigation zone is specially evident in the study area. In the early 1950s, when irrigation started to develop along the São Francisco River, a number of state and federal banks and agencies became involved in encouraging the expansion of the activity as well as in financing technical improvement. The Banco do Nordeste do Brasil, together with the Banco do Brasil and the Banco do Estado de Pernambuco, provided loans for the establishment of the necessary infrastructure on private farms, particularly for the acquisition of water lifting devices. With this credit farmers were able to purchase, successively, waterwheels, diesel pumps and electric pumps. This was also done in association with the SUVALE, the Ministry of Agriculture, the Pernambuco State Secretariat of Agriculture, local agricultural co-operatives and the Rural Electrification Cooperative.

Perhaps the most important factor in the expansion of irrigation after 1950 was the improvement of transport facilities which permitted access to the growing urban consumer markets. Roads were widened and straightened, new foundation was laid and bridges were built on most important highways. These improvements allowed for faster lorry movements to and from the Northeast, so that agricultural products, especially perishables, could be taken to urban markets in both the Northeast and the Southeast. In addition, new products entered the region at a cheaper price and new needs arose among the local population. Not only were farmers able to sell an increased amount of production but they also had something to spend the greater income on. Hodder (1973), Malassis (1975) and Wolf (1966) have shown elsewhere that this kind of market penetration is a classic way of transforming peasant agriculture. The processes of change were intensified in the mid-1960s when main roads began to be asphalted and secondary roads were improved.

By the 1960s, irrigation was found in many counties of the Northeast, not only in the Sertão but also in humid areas as well. Even at this date the Semi-Arid Zone already stood out as the part of the Northeast where more irrigation was encountered, with 63% of the total area (Table 17). However, irrigation was generally confined to areas where an abundance of water existed, such as along main rivers like the São Francisco, Jaguaribe and Açu, or in humid mountains like the Chapada da Diamantina in Bahia and the Chapada do Araripe in Ceará. Irrigation could also be encountered in other places where it was practised on a small scale. In all, 52% of the counties of the Sertão had irrigation at that time. Of the counties of the Northeast, be they semi-arid or humid, 37% had at least some irrigation in 1960. Nevertheless, irrigation was still relatively insignificant and it did not occupy more than 1% of cropping land in most zones of the Northeast.

Table 17. Expansion of Area under Irrigation between 1960 and 1975 in the Northeast.

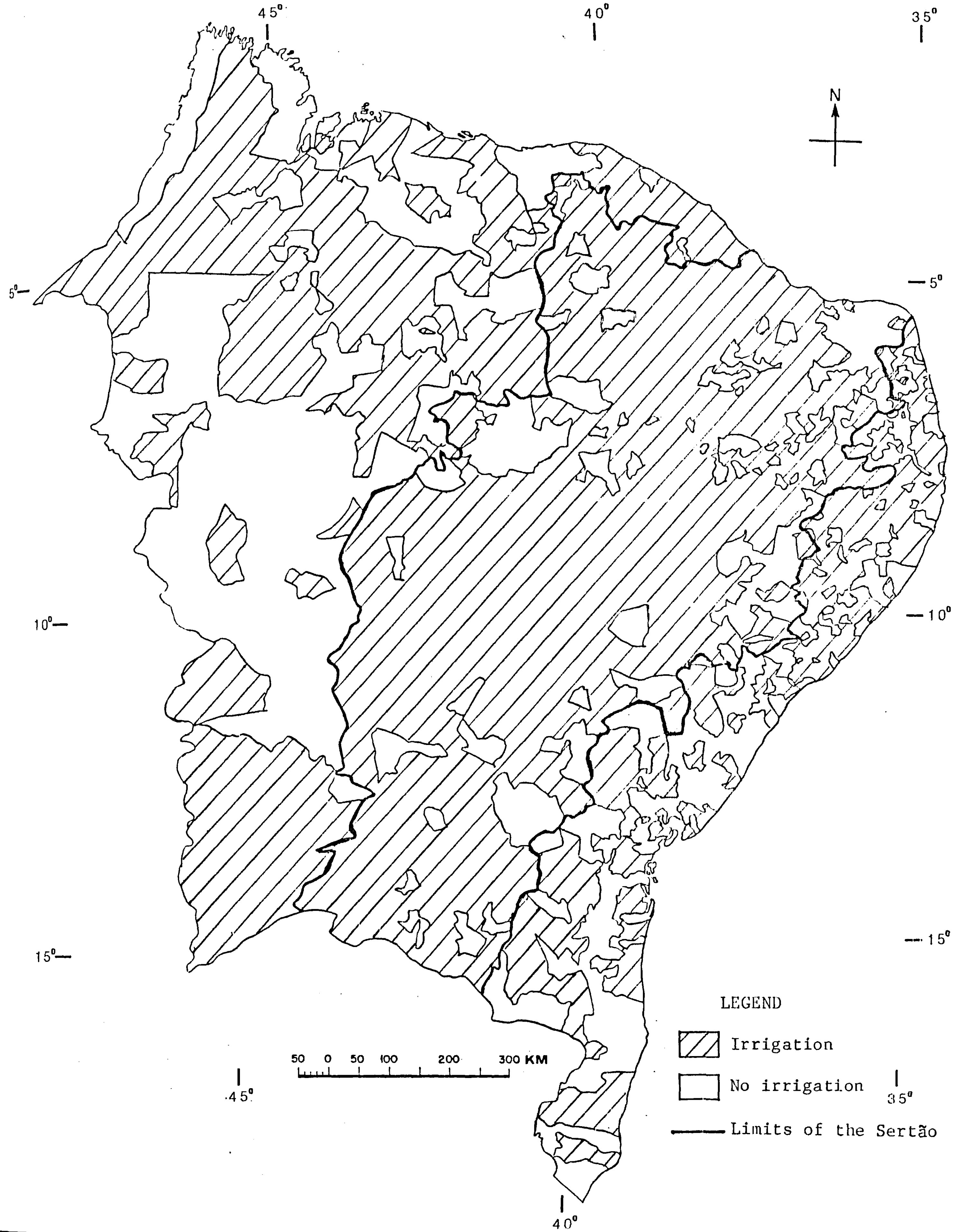
Zones	1960 Total Cropping (1000 ha)	1960 Irrigation (1000 ha)	1960 %	1975 Total Cropping (1000 ha)	1975 Irrigation (1000 ha)	1975 %	Annual Growth Irrigation 1960/75 (%)
Zona da Mata & Litoral	2219	13.3	0.6	2707	73.0	2.7	29.9
Agreste	1560	1.0	0.1	1598	10.7	0.7	63.6
Sertão	3625	32.3	0.9	5195	70.7	1.4	7.9
Meio-Norte & Gerais	1275	5.5	0.4	1536	9.0	0.6	4.1
Total	8679	52.1	0.6	11036	163.4	1.5	14.2

Source of Data: Fundação IBGE (1966, 1979).

By 1975 irrigation had spread to most parts of the Northeast and 57% of the counties had some irrigation (Figure 6). The Sertão and Zona da Mata continued to be where more irrigated area was found, with 43% and 45% respectively of the total of the Northeast. The principal irrigated areas of the past in the Sertão maintained their prominence and their area expanded significantly. Important new irrigation zones arose in other localities, such as in the lower São Francisco River in Alagoas and Sergipe States, Sobral and the Sertões do Canindé in Ceará State.

Between 1960 and 1975 the irrigated area more than doubled in the Northeast. The activity was still being practised on a small minority of crop lands but it expanded rapidly. In the Sertão, the area under irrigation expanded at a rate of 7.9% per year as compared to 2.9% for the area under rain-fed cropping.

The expansion of private-sector irrigation from 1960 to date has gone wholly unnoticed by most development agencies. The view of the government, as expressed in various plans such as DNOCS (1976), GEIDA (1971) and MINTER (1973), was that private-sector irrigation was nearly non-existent in the Sertão and what there was, did not expand fast enough. It never occurred to the thousands of government planners involved in the subject to consult official census data to verify this or to carry out a survey in the region to investigate the situation. Indeed, one wonders whether this oversight was deliberate, because in practice many of the government irrigation and hydro-electric projects replace areas of existing private-sector irrigation.



Source of Data: IBGE (1979).

Figure 6. The Distribution of Irrigation in the Northeast in 1975.

GOVERNMENT PROJECTS

During the 1960s the government revived its old plan to establish public irrigation projects. As Hall (1978) shows, at the insistence of SUDENE, DNOCS and SUVALE were finally prodded into taking concrete action. DNOCS received large amounts of federal funding to amplify its activity on large public reservoirs and SUVALE, whose name changed to the Companhia de Desenvolvimento do Vale do São Francisco (CODEVASF), was also empowered to do so in its areas of jurisdiction.

Although the ideology of the new projects is similar to that of those of the 1930s and 1940s, some important changes have been made in the programmes. The central idea continues to be the creation of public irrigated areas to be exploited by landless peasants on a co-operative basis. The great break with the past is in the scale of the operations. Each project is installed in an enormous area, which is expropriated from private farms. One of the principal justifications for this policy is to replace idle latifundias with more efficient family farmers. The sites selected are often those best suited for irrigation where rich soils and water are readily available. As the process of diminishing farm size is more advanced in these places numerous smallholdings are expropriated and not many large properties.

The first impact of the expropriation of such large areas is the dislocation of great contingents of population that reside in the area of the project. These give way to another group of well selected families that receive the land in their place. In zones of greater population density, such as in Ceará and Paraíba, many more farmers leave the area than are settled on the projects (Hall, 1978). In less populated zones, like the São Francisco River and some of its tributaries in the study area, about an equal number are removed as are settled.

The projects are mounted with a sophisticated capital-intensive irrigation system which is said to be necessary for the achievement of large-scale production. Increasingly, big is considered beautiful. The area of the projects gets larger, the technology more impressive as well as expensive, and the overall production is greater. The new government mentality is one of efficiency, which is achieved through instilling an entrepreneurial attitude in project farmers of peasant origin.

Most of the new government projects are located where experimental farms previously existed. DNOCS intends to establish 29 projects with 95928 irrigated hectares tilled by 19188 family farmers. However, DNOCS has been encountering long delays in setting up projects and in settling farmers on their plots. Of the planned total number of project farmers, 9880 should have been settled by 1979 but only 2053 actually had been by 1981 and they represented only 11% of the final planned total. Similarly, of the 42929 irrigated hectares that were supposed to have been in operation in 1979 only 11552 were being tilled at that date. This was only 12% of the total planned (Table 18).

CODEVASF is almost as far behind schedule. The agency intends to establish eight projects in the Sertão, all of which will have areas for family farmers, large capitalist farmers and agribusinesses. Of the total of 62879 hectares planned, roughly one-third will be for family farmers and two-thirds for large capitalist farmers and agribusinesses. In 1981 only 329 family farmers were tilling a mere 3130 hectares on three functioning projects and two capitalist farmers were planting 217 hectares on one of these. Two agribusinesses were working 4100 hectares on one of the three projects and on another project which did not as yet have any family farmers. Of the total area planned for 1979 only about 35% was operational in 1981 and this was only 12% of the final goal (Table 19).

Table 18. Irrigated Area and Farmers Settled on DNOCS Projects in the Sertão.

Project	Irrigated Area (Ha)			Farmers		
	Planned		Operational	Planned		Settled
	Total	1979	1979	Total	1979	1981
PIAUÍ						
Vale do Fidalgo	580	580	114	260	260	25
CEARÁ						
Aires de Souza	615	615	60	210	210	25
Forquilha	192	192	214	91	91	61
Baixo Jaguaribe	26343	6000	0	5154	1500	0
Banabuiú-Morada Nova	10143	8883	2932	3189	2713	476
Icó-Lima Campos	3021	3021	1936	612	612	339
Jaguaruana	189	189	200	40	40	50
Santo Anto. dos Russas	189	0	0	70	0	0
Quixabinha	120	120	109	24	24	24
Riacho do Sangue	94	0	0	52	0	0
Vale dos Carás	n.a.	0	0	n.a.	0	0
Várzea do Boi	287	287	258	117	117	84
RIO GRANDE DO NORTE						
Pau dos Ferros	1130	1130	0	131	131	45
Baixo Açu	18000	1420	0	2816	260	0
Estevam Marinho	4500	0	0	900	0	0
Itans-Sabugi	1126	1126	420	134	134	71
Cruzeta	194	194	110	24	24	23
PARAÍBA						
Engenheiro Arcoverde	281	281	281	51	51	37
São Gonçalo	3350	3350	1911	515	515	305
Sumé	320	320	210	51	51	47
Poções	n.a.	0	0	n.a.	0	0
PERNAMBUCO						
Custódia	300	300	209	100	100	50
Cachoeira II	162	162	183	37	37	43
Boa Vista	154	154	77	26	26	26
Saco II	486	486	0	82	82	0
Moxotó	3822	3789	1296	426	426	198
Entremontes	2000	2000	0	1000	1000	0
BAHIA						
Jacurici	1000	1000	114	200	200	20
Contas-Brumado	15500	5500	0	2510	910	0
Vaza Barris	1830	1830	918	366	366	104
TOTAL	95928	42929	11552	19188	9880	2053

Source of Data: DNOCS (1976) and Diretoria Geral do DNOCS.

Table 19. Irrigated Area According to Type of Farmer on CODEVASF Projects in the Sertão (Ha).

Project	Planned		Operational
	Total	1979	1981
Bebedouro	2060	2060	1277
Curaçá	4500	2000	0
Mandacaru	370	370	370
Maniçoba	5025	5025	1400
Massangano	16000	0	0
Petrolândia	900	900	900
Salitre	23000	0	0
Tourão	11024	11024	3500
TOTAL	62879	21379	7447

Source of Data: CODEVASF (n.d. 2) and Field Research.

As the federal government is presently in financial difficulties, the funds for both agencies have been reduced although there is great pressure to achieve results. The rush to begin irrigating, in turn, has contributed to shoddy infrastructural work being done which threatens the long-term success of the projects.

Another important change from the days of the experimental public farms is the discontinuance of the external cooperation programme with private farmers outside the project areas. These farmers are now supposed to watch from the outside, and the success of the projects is expected to provide incentive for them to improve their own irrigation systems. Unfortunately, the projects are closed off to the general public, hence most private farmers cannot observe public irrigation methods. Also, rural extension for private farms is no longer provided by DNOCS or CODEVASF but rather by a separate entity, EMATER, whose personnel are overtaxed in their work.

DNOCS and CODEVASF have, therefore, embarked on a programme to implant sophisticated irrigation throughout the Semi-Arid Zone. This is proving to be an extremely slow and costly undertaking. Given this, it has become imperative for the agencies to prove the success of the high investment projects. As usual, consideration of quantity is what matters and questions of quality are given scant attention. How many hectares are in irrigation? How many families have been settled on the projects? How much is invested and how much is produced? The larger the numbers the better the projects appear to be. Unfortunately little is asked and said about the effects of the projects on the Sertão itself. Nor have many planners wondered whether such high technology irrigation can diffuse throughout the region without heavy government subsidy. Finally, there is almost total official silence as to how public irrigation compares to private-sector agriculture, whether irrigated or not.

In fact, when someone within government raises such a question, he is pressured to remain quiet, such as occurred with some noted SUDENE experts. In recent years SUDENE has become timidly critical of the viability of CODEVASF and DNOCS plans but the influential directors of the agencies have bypassed SUDENE. In theory both irrigation agencies are under SUDENE's jurisdiction and the plans of each have to pass through its offices on their way for final approval in the Ministry of Interior in Brasília. In practice, though, SUDENE's role has become restricted to merely offering its opinion and to passing government funds on to the agencies. Even the international funding agencies are starting to balk at lending more money to finance more and more public irrigation lands which, in their view, are not producing enough, given the scale of investment.

From 1970 to the present, irrigation in the Sertão can be viewed from two perspectives: private and public. The two have become completely separate, at times co-existing side by side, while in other instances they compete for the same area. Private-sector irrigation is virtually ignored by the government, yet it is responsible for the overwhelming majority of irrigation farmers and farmland in the Sertão.

In 1975, the 5259 hectares on DNOCS projects and the 1000 hectares on CODEVASF projects accounted for a mere 0.1% of the cropping area of the Sertão. Furthermore, the 6259 hectares under public domain represented only 8% of the total amount of irrigated land. The rest of the area, 65007 hectares, is on private farms. The 1061 farmers on the projects in 1975 represent only 5% of the Sertanejo farmers who use irrigation. There are another 21766 irrigation farm owners in the private sector who account for 95% of all irrigation farmers 1975 (Fundação IBGE, 1979).

IRRIGATION TECHNOLOGY TYPES

According to the model of irrigation technologies presented previously, all three types of irrigation - labour-intensive, intermediate and capital-intensive - are encountered in the Sertão. Private-sector irrigation shows considerable variation in technology type while public-sector irrigation is invariably capital-intensive by design. Throughout the rest of this work the flexibility in choice of farm technology in the private sector will be shown to explain why the majority of irrigated area and nearly all irrigation farmers are found in the private sector rather than on the public projects.

Distribution of Irrigation Technology Types

Different irrigation technologies are found within the Sertão and the one which predominates in a particular place varies according to local environmental and socio-economic conditions. The use of intermediate and capital-intensive forms of irrigation is usually associated with a greater scale of farm operations so that they are found where soil and water resources are abundant and where farmers possess more capital. Labour-intensive irrigation is the main type found in places where limited water supply and poor soil conditions do not permit the practice of irrigation on a large scale. In addition, this type of irrigation is utilized where farms are small and where farmers possess limited capital resources or have restricted access to such resources. Hence, this is the main type of irrigation found in dispersed localities where one or another farmer uses irrigation and the vast majority still utilize dry farming.

The whole range of irrigation technology types are encountered in the study area (Plates 1 & 2). The lower-middle São Francisco Valley is the most important irrigation zone of the Sertão because ideal ecological and socio-economic conditions are present. Irrigation arose on a larger scale there and has developed rapidly so that it is one of the few places in the Northeast which can be qualified as an irrigation region. Irrigation was first introduced along the perennial main stream of the São Francisco River and this became an irrigation core area. The activity as well as technical innovations then diffused up the seasonal tributaries.

In order to classify the farms of the study area in a precise way an irrigation technology index was devised (Appendix 2). Elaborating on the world-wide model presented previously, the following classes are distinguished: a) labour-intensive, index value of less than 40; b) low intermediate, index value of 40 - 55; c) high intermediate, index value of 56 - 70; and d) capital-intensive, index value of more than 70.

Plate 1. Irrigation system on a labour-intensive farm. Small field of onions planted in inundation basins, located on the edge of a reservoir (Chorrochó County, 1981).

Plate 2. Irrigation system on an intermediate technology farm. Large polyculture field and areas in fallow (Belém do São Francisco, 1977).

When classed according to the index, the majority of private-sector farms of the study area fall in the intermediate technology category and this is true whether they are located on the São Francisco River or along its tributaries (Table 20). Where the areas differ is in the frequency of the other two types of irrigation technology. On the main stream, labour-intensive technology is used on only 4% of the farms, while the capital-intensive type is utilized on 22% of the farms. Labour-intensive irrigation is more common on the tributaries. About a third of the farmers use this type there and none use a capital-intensive technology.

Table 20. Private-Sector Irrigation Technology in the Study Area.

Technology Type	São Francisco River n	%	average index value	average irrigated area (ha)	Tributaries n	%	average index value	average irrigated area (ha)
Labour-intensive	2	4.4	34.6	1.0	9	36.6	35.3	4.7
Low intermediate	20	43.5	47.2	9.1	11	42.3	48.2	3.0
High intermediate	14	30.4	59.2	31.1	6	23.1	61.2	17.7
Capital-intensive	10	21.7	77.9	121.8	0	-	-	-
Total	46	100.0	57.0	39.9	26	100.0	46.9	7.0

Source of Data: Field Research.

When examining the sub-division of the intermediate type, more differences can also be detected between these areas. Along the São Francisco River, the lower intermediate type is utilized on about 44% of the farms and the high intermediate type is used on somewhat more than 30% of them. On the tributaries, 42% of the farmers use the lower intermediate type of irrigation and 23% use the higher type. In sum, farms along the São Francisco mainstream have a more capital-intensive technology while the farms of the tributaries have a less capital-intensive type, on average about 10 points lower on the scale. In addition, the scale of irrigation farming along the main stream is much larger than that of the tributaries and, as will be explored in greater detail further on, it is exactly this scale which makes it possible to exploit more capital-intensive forms of irrigation.

The capital-intensive nature of public-sector irrigation can be seen in the high technology index value of 88.2 registered. Such a level can be attained because the production unit is the project. Overall irrigation area is large even if family plots are small. The nature of the technology used in the public sector, therefore, requires considerable scale in the size of the production unit as well as in administrative complexity.

Technological Change

a) Private-Sector Irrigation

When looking at technological change in private-sector irrigation of the Sertão, a gradual evolution is observed to have taken place. The study area provides a good example of this process whereby progressive change from a technology that uses less capital towards one that employs more capital have occurred. Change was most evident in water lifting devices, in irrigation method, in mechanization, and in the use of selected seed and pesticides.

The fact that the mainstream irrigation core area along the São Francisco River is the most important irrigation area of the Sertão, and that irrigation has been practised longer there than in most places, partially explains why a more capital-intensive type prevails. Nevertheless, farmers adopting irrigation at a later date in other places need not pass through the same stages as the pioneers did. Moreover, the time necessary to change from one technology type to another varies immensely. It can take decades or just one or two years. While it took thirty years for the type of irrigation practised on the main stream to reach the point it has today, when the activity is taken up on the tributaries it can already diffuse at a higher level than that of the initial years at the point of origin. And this is particularly true for delicate cash crops like onions, melons and tomatoes which produce best when using a considerable amount of industrial inputs.

The first irrigation system that arose in the late 1940s along the lower-middle course of the São Francisco River was of a labour-intensive type.. Fixed and operating costs were low and industrial inputs were used sparingly. With time, farmers experimented with different technical innovations, adopting and adapting them to their financial situation and to the local environmental conditions.

The original water lifting devices introduced were waterwheels, which used the cost-free natural force of the strong river currents in that part of the São Francisco River. The waterwheels were made by local craftsmen from timber that was supplied from nearby sources, or brought downstream from the Gerais zone. Pierson (1972) reports that waterwheels were rapidly set up, with their number increasing from one in 1948, to 21 in 1952 and to 105 by 1958.

However, diesel motor powered pumps were soon adopted, for they provided greater amounts of water at a faster rate, which, in turn, enabled the irrigation of larger areas to be carried out. By the late 1950s the Banco do Nordeste do Brasil (1957) reported that about 90% of the water lifting devices being used were deisel pumps rather than waterwheels. Also, waterwheels were liable to be damaged during floods. On the other hand, motors were more liable to break down, which could cause harvest failure if the water supply was not restored within a week or two.

In the mid-1960s a programme of rural electrification enabled the adoption of electric pumps, which are much more reliable and cheaper to operate. However, when counting the costs of installing electricity on the farm and acquiring the pump itself, the initial investment is higher than that of a deisel pump. In 1977, while a diesel pump cost US$ 2200, a fully installed electric pump cost US$ 4190. Electricity is expensive to install because of the high cost of the transformer, which the state electric company does not furnish in the rural zone as it does to users in the urban zone.

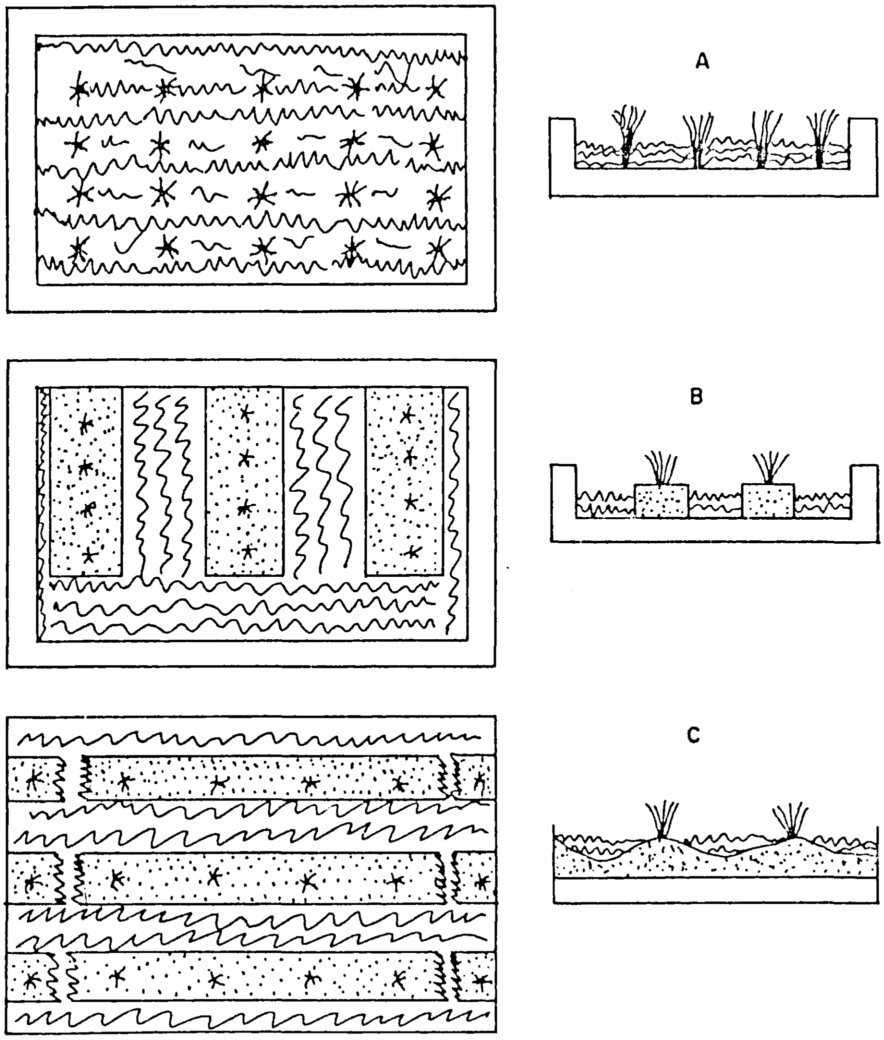
Hençe today, while 66% of the 46 mainstream farmers interviewed use electric pumps, a third still use diesel pumps. These farmers are smallholders and tenant farmers who do not possess the means of installing electric pumps. A number of large farmers have diesel pumps in addition to electric ones, which they use when an occasional main line transmission failure takes place. Only one interviewed farmer still uses a waterwheel, which he utilizes at all times so as to reduce his electricity bill. However, the initial cost of a metal waterwheel is expensive nowadays. In 1977 one cost US$ 8380.

Rural electrification and an arrangement for the purchase of electric pumps and installations through a co-operative were especially important for stimulating the expansion of irrigation. Unfortunately this, together with a programme of subsidized bank loans for irrigation, were mainly restricted to the Pernambuco side of the São Francisco River. With the exception of Juazeiro county, the Bahian side languished. By 1970, there were 7819 hectares in irrigation on the Pernambuco side and only 1196 hectares on the Bahian side, of which 786 were located in Juazeiro county. By 1975 the difference was even greater, with 13179 hectares on the Pernambuco side versus 2686 on the Bahian side (Fundação IBGE, 1975b, 1979).

On the seasonal tributaries of the São Francisco River, where electricity is not available and where there is obviously little river current, diesel motors are still the rule and this acts to slow the expansion of the irrigated area there as well. In 1970 the Census reported a mere 83 hectares of irrigation in the huge county of Parnamirim, which covers 2478 km^2. By 1975 this had grown to 147 hectares. Terra Nova is a small county, covering 266 km^2, which is located closer to the mainstream core area and, while a lack of rural electrification there acts to slow the expansion of irrigation, the area in irrigation increased faster than in Parnamirim. In 1970 only 32 hectares were irrigated, while by 1975 this had risen to 187 hectares (Fundação IBGE, 1975b, 1979).

Apart from a few very large farms, <u>water distribution systems</u> do not yet require much capital. Most farmers still use earth canals and only one or two larger farmers have installed a few hundred metres of cement-lined canals. Water supply along the perennial São Francisco River is still relatively plentiful and irrigation fields off the main stream are modest in size, so most farmers see little advantage in making such an expensive investment in order to economize water. The problem of excessive water loss through seepage, which could prevent the irrigation of land further away from the source of water, has been overcome with the use of inexpensive plastic pipe. These have become available in recent years and allow poorer farmers to irrigate larger areas than they could previously.

Currently, there are three types of <u>irrigations methods</u> (Figure 7). The oldest is inundation basins where, at the moment that water passes along the canal, a break is made in the retaining wall, the water is let in and then the wall is closed again. Two newer types are furrows and basins with raised planting areas. In furrow irrigation, crops are planted in long, raised areas and water reaches the crop by



A - Inundation Basins

B - Basins with Raised Planting Areas

C - Furrows

Figure 7. Irrigation Methods Used in the Sertão.

lateral infiltration from the furrow. The furrows receive water directly from secondary canals, either by breaking the retaining wall of the canal or by using plastic hoses which siphon water over the wall. Water arrives in basins with raised planting areas in the same way as in inundation basins but, like furrow irrigation, water reaches the plants by lateral infiltration and does not come into direct contact with the plants.

Agronomists favour furrow irrigation. One chief advantage of furrows is the isolation of plants from one another so that disease is not transmitted by way of the water as can occur with basin irrigation. Furrows also permit the planting of more crops per irrigated area because less of the field is taken up by basin retaining walls. Finally, furrows are more amenable to mechanization as they are cut using a disc pulled by a tractor and so less manual labour is needed in preparing the land.

On the other hand, local farmers point out that furrows have to be watered more often because the water is not retained in a basin and so more electricity or fuel expense is involved in their use. Also farmers (of whom one is an agronomist) claim that furrows worsen problems with salinization. Despite using less water per watering, more waterings per week are needed and this can cause more salt to rise and accumulate at the surface. They say that inundation basins using more water less times forces salt down in the soil. Finally, land must be flat in order to use furrows, and in the absence of this, it must be levelled with bulldozers, which is an expensive undertaking.

The solution of local farmers to balancing the risks and advantages involved with basins and furrows was to adopt both in the form of basins with raised planting areas. Plants receive water through lateral infiltration, thus controlling disease. Less watering is needed, even if some area is lost to the basin retaining walls.

However, some crops can only be grown by one type of irrigation method. The foliage of melons and watermelons spreads out over the ground and fungi develop if it comes in contact with water, so that only furrows are used for these crops. Similarly, manioc has always been grown in long raised mounds, which resemble furrow irrigation, so that the tuber does not rot by receiving too much water. The reason is less clear why tomatoes should be grown with furrow irrigation, other than that the crop was recently introduced into irrigation in this form. Rice has to be grown in inundation basins as it must receive large amounts of water in order to remain well immersed throughout the crop cycle.

Variation in irrigation method is seen in the important crops of beans and onions. Inundation basins are used by 19% of the 34 interviewed farmers along the São Francisco River who plant onions, almost all of whom farm in marginal areas of the onion zone, while 73% use basins with raised planting areas and only 18% use furrows. Of the 31 interviewed farmers who plant beans, 21% use inundation basins, 76% basins with raised planting areas and 18% use furrows. These latter were participating in an experimental project with the local rural extension office. The farmers did not like the results and the majority reverted to basins with raised planting areas afterwards. However, those who plant beans destined for government selected seed are required by the state to plant in furrows. The same farmers, when planting beans not destined for selected seed, use basins with raised areas. Farmers who use furrows only use them during the first half of the year when evaporation is lower, while in the second half they use basins with raised planting areas in order to economize on water costs.

The situation on the tributaries reflects an earlier phase in the expansion of irrigation. Of the 18 interviewed farmers who plant beans and onions there, 57% use inundation basins, only 30% use basins with raised areas and none use furrows for these crops. Furrows are used by only a few farmers who crop melons and watermelons which have to be planted in this manner.

Since the early 1970s, tractors have become more numerous locally and at the time of the research 60% of the irrigation farmers on the main stream were using them as were 37% of those on the tributaries. Irrigation requires greater land preparation than does dry farming and greater income obtained from irrigation enables farmers to use tractors. Cash crop market considerations are also important for encouraging the use of tractors. Farmers want to prepare their land for planting as soon as possible after the period of heavy rainfall in order to take advantage of favourable market conditions. However, the field must be large enough to compensate the use of a tractor. Hence, fewer smallholders use tractors because they can manage land preparation manually or with animal traction. This is particularly true on the tributaries where most farmers only irrigate three or four hectares.

The use of selected seed arose with onion growing because the climate did not allow seed cropping. For a long time imported Californian seed was the sole source and only during the last few years has nationally produced seed become available. When melon, tomato and watermelon irrigation cropping arose, farmers were already accustomed to using selected seed in onion irrigation and so they preferred to use this type of seed instead of trying to select their own. With the exception of watermelons, local farmers were not very familar with many of the new crops. At the time of research, selected seed for staple crops was not available locally, so farmers use their own seed. The quality of this seed is so good that a number of irrigation farmers now supply the state seed service.

Onions, tomatoes and melons all require fertilizers, insecticides and fungicides in order to produce properly. Herbicide is available for onions and is used by all farmers who plant this crop. Fertilizer and pesticide can be used for these crops because they normally offer the highest payoffs. Other crops, such as beans, maize, manioc and rice do not, and fewer farmers use these inputs on staples. Scale of production is also important for encouraging the use of pesticides. Few farmers irrigate fruit trees and watermelons on a large scale, and only those who do, regularly utilize pesticides and fertilizers on them (Table 21).

Table 21. Use of Fertilizers and Pesticides by Private-Sector Irrigation Farmers of the Study Area

Activity	Farmers Planting Crop	Farmers Using Fertilizers		Farmers Using Pesticides	
		n	%	n	%
STAPLE CROPPING					
Beans	41	7	17.1	21	51.2
Maize	12	1	8.3	4	25.0
Manioc	7	0	0	0	0
Rice	16	2	12.5	2	12.5
CASH CROPPING					
Fruit trees	8	3	37.5	3	37.5
Melons	9	9	100.0	9	100.0
Onions	52	52	100.0	52	100.0
Tomatoes	9	9	100.0	4	44.4
Watermelons	10	6	60.0	3	33.3
STOCK-RAISING					
Planted pasture	7	2	28.6	2	28.6

Source of Data: Field Research.

Harvesting is still done manually for all irrigated crops. The only mechanized aspect that has been recently introduced is a machine in the local government wholesale market which cleans, grades and sorts onions for shipment. However, the traditional method of weaving onion stems in large bunches is still preferred by most farmers and buyers alike. Onions are easier to transport to market when they are woven in bunches and do not spoil so quickly while on the road to distant markets.

A good deal of technological change has, therefore, occurred in private-sector irrigation farming and within a fairly short period. The development agencies, though, are ignorant of this. Government plans and reports continue to refer to the need to transform 'archaic', 'old fashioned' and 'rudimentary' Sertanejo farming. Planners still think that the point of departure is a slash-and-burn system of rain-fed cropping where no industrial inputs are utilized. This is no longer true for dry farming let alone for private-sector irrigation.

b) Public-Sector Irrigation

National economic policy is one of accelerated development so the objective is to skip intermediary stages of technological change and to introduce at a stroke what is considered to be modern irrigation farming. Hence, only capital-intensive technology is used in public-sector irrigation. In consequence, it is the most sophisticated and inflexible farming system found in the Sertão.

DNOCS projects are located on seasonal rivers, so that water is supplied by huge reservoirs whence it flows by the force of gravity in aquaducts and tunnels. Nearly all CODEVASF projects are located near the São Francisco River, but not on the river's edge. Water is drawn up from the river at large pumping stations and then passes through a series of sub-stations to fields located a few kilometres inland or, in some cases, ten to twenty kilometres inland. Both DNOCS and CODEVASF rely on concrete-lined primary and secondary canal systems. Even long moulded-concrete aquaducts are found on some projects (Plate 3).

Plate 3. Irrigation system on the capital-intensive CODEVASF Bebedouro project. Main canal, siphons, sieve to secondary canal, fields in distance and unutilized areas in foreground (Petrolina County, 1981).

Furrow irrigation is the rule and extensive levelling of land is done so that this method can be utilized (Plate 4). Project farmers are forbidden to use any sort of inundation basins and, as a result, land which cannot be levelled is left untilled. Mechanization is used wherever possible and all essential land preparation is done by tractor. Extension agents instruct project farmers to use large quantities of insecticides, fungicides, herbicides and fertilizers in order to obtain the highest yields possible.

Plate 4. Earth moving equipment being used to level land on the capital-intensive CODEVASF Tourão project (Juazeiro County, 1981).

There are, therefore, two different philosophies concerning what sort of irrigation technology is best suited for overcoming the problems of the Sertão. On one hand, the government is pursuing a policy of direct intervention in which capital-intensive irrigation is established at once. Hodder (1973) and Hunter (1969) have demonstrated elsewhere in the developing world that this kind of abrupt rural change causes problems not only in relation to the human resources of these countries but also in respect of economic and ecological conditions. The same kind of difficulties will be shown to arise in public-sector of the Sertão. On the other hand, a number of technological options are found in private-sector irrigation of the Sertão and each is appropriate for the widely varing ecological and socio-economic conditions encountered throughout the zone.

With respect to appropriate technology, a number of questions arise which will be addressed in the rest of this thesis. These include considering where irrigation can be adopted and which type is most suitable for different parts of the Sertão. Who adopts irrigation and which kind? Is irrigation economically viable? Does irrigation resolve the basic Sertanejo problems?

6. THE ENVIRONMENTAL BASIS FOR THE PRACTICE OF IRRIGATION

If considerations of local rainfall patterns are of paramount importance for dry farming, the availability of water resources is the crucial environmental factor for the practice of irrigation in the Sertão. Without enough good quality water irrigation is simply not possible. Similarly, soil conditions can make or break the success of irrigation, and this involves more than questions of soil fertility. Soils chemistry and texture must be of a type which do not pose the hazard of long-term salinization.

In the first part of the chapter, the hydraulic resources of the Sertão are analysed with respect to whether the amount of water and quality of water in the zone is conducive to the practice of irrigation. In most of the Sertão, both groundwater and surface water are shown to be quite restricted in quantity and to be of medium salinity. Similarly, in the second part of the chapter, good soils which do not pose the hazard of salinization are also shown to be scarce. The basic conclusion drawn is that natural limitations pose serious implications for the practice of irrigation. Large-scale irrigation - and especially capital-intensive types - are not readily sustained and can be utilized in few places. Small-scale, intermediate and labour-intensive irrigation can be practised along most rivers of the Sertão but only if great care is exercised. Unfortunately, the long-term environmental consequences are seldom considered. Both public- and private-sector irrigation are being introduced in such a way that salinization is likely to occur.

WATER RESOURCES OF THE SERTÃO

All water resources of the Sertão, be they surface water or groundwater, ultimately come from the rains that fall in the region. As was mentioned previously, patterns of precipitation are highly irregular and this profoundly affects the absolute supply of water and its seasonal availability. Strong insolation and constant high temperatures cause intense evaporation which severely diminishes the amount of water that runs off or infiltrates into the soil (MINTER, 1973; Nimer, 1977; Silva & Lima, 1982; SUDENE, 1973, 1974). However, water supply for irrigation is not simply a question of local rainfall but more one of river flow and groundwater supply.

The geological features of the Sertão affectin the availability of water resources mainly by limiting the infiltration and retention of water in the ground. The lithology of the Sertão can be separated into two groups, crystalline and sedimentary rock formations, each of which affects run-off and infiltration in different ways. As a rule, more water is available in sedimentary areas.

Merely examining the quantity of water in the Sertão is not enough to assess its potential for irrigation. The quality of the water, and particularly its salinity level, is of paramount importance for the practice of agriculture in more arid environments (Falcão, 1980; USDA, 1953; Withers & Vipond, 1974). The presence of salt in irrigation water can restrict the number of species that can be planted, retard the growth of plants and contribute to the salinization of soils. In the Sertão, the quality of water is affected by the climate and geology. The water ranges from being nearly salt free in some sedimentary areas to being highly saline in some crystalline areas, though most is of low to medium salinity.

Mainly surface water is used for irrigation in the Sertão. Groundwater is usually difficult to find, limited in volume and frequently too saline to be suitable for agriculture. Many of the same problems are encountered in the the supply and quality of surface water and this can limit the type of irrigation which can be utilized.

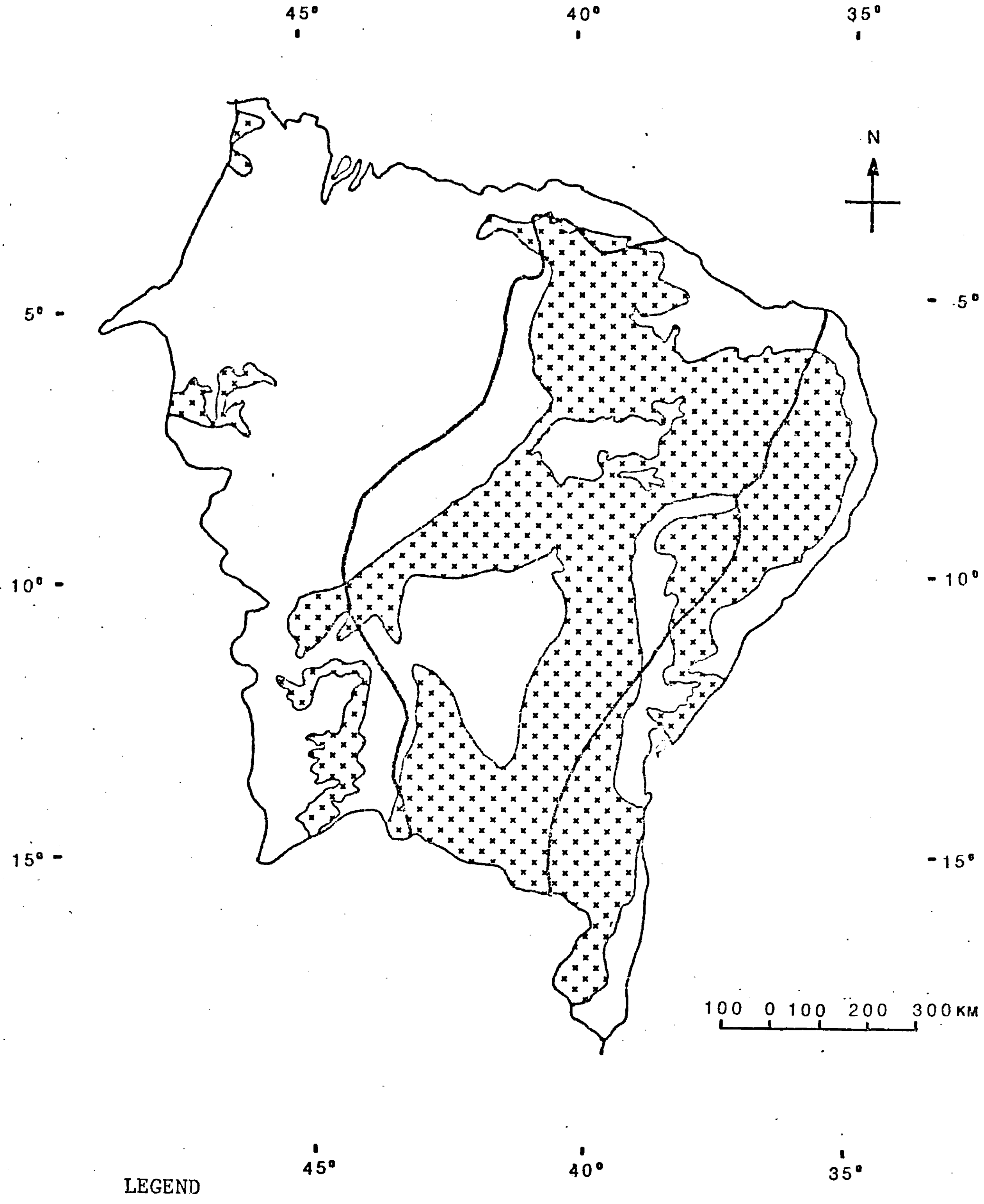
Groundwater

a) Quantity of Water

As a result of the climatic conditions not much water is available to infiltrate into the ground and the infiltration which occurs is extremely irregular as a response to rainfall. According to SUDENE (1979) less than 8% of the rainfall is converted into "mobile" water. This is that part of the rainfall which runs into rivers or infiltrates downward into the water table. The greater majority of rainfall is either directly absorbed in loco by the parched soils or evaporates into the atmosphere.

Together with the climatic conditions, there are important geological factors which reduce the potential of groundwater. Crystalline and sedimentary rock formations yield different amounts of groundwater.

Crystalline rock formations are found in the majority of the Sertão (Figure 8). As the porosity and permeability of crystalline rock are very restricted, there is little possibility for the existence of significant groundwater accumulations in these places. On the other hand, some crystalline areas have been affected by tectonic processes whereby fractures and faults have been formed. This, together with weathering, allows some infiltration to occur and groundwater can be encountered in these places. Nevertheless, as a rule, groundwater is scarce in crystalline areas. Surveys have shown



LEGEND

Limits of the Sertão

Crystalline Areas

Sedimentary Areas

Source: MINTER (1973).

Figure 8. Lithology of the Northeast.

that the estimated average discharge per prospected well in crystalline areas is a mere 3 m^3 per hour and discharge is 108 $lt/h/m^3$ at a depth of 30 metres (SUDENE, 1973).

Groundwater is more abundant in sedimentary zones, but this kind of rock formation only covers a third of the Sertão. In these areas, good soil porosity and permeability permits greater infiltration, though, discharge per well is still normally only 10 m^3 per hour. Estimated average discharge by area varies from 10 m^3 to over 100 $m^3/h/10\ km^2$. The upper limit is only obtained in a few isolated localities and the usual discharge is a maximum of 20 $m^3/h/10\ km^2$ (SUDENE, 1973).

b) Quality of Water

The quality of groundwater in the Sertão, once again, is adversely affected by the climatic and geological conditions of the region. Salt minerals present in the rock formations are dissolved when they come into contact with infiltrating water and high rates of evaporation also cause the build-up of salt.

As aridity and salinity of groundwater are highly correlated, climate is the usual explanation given for groundwater salinity (SUDENE, 1973). Lithology is also an important consideration because groundwater is more saline in crystalline areas than in sedimentary areas.

These two explanations are criticized by those who argue that the salinity of groundwater is far too high simply to be derived from the chemical dissolution of salt found in rock and its subsequent concentration by climatic factors. The high concentration of salt is considered to be of marine origin and the predominance of magnesium over calcium is taken to indicate this. Salt deposits were laid down during the Cretaceous Period when the area that is now the Sertão was covered by the sea (Falcão, 1980).

The fourth and most recent idea that has been proposed to explain salinity relates climate and geographic location. Salt laden air is carried inland from the sea by the prevailing winds. Once blown inland the salt settles on the land and is then leached downward into the soil or is washed by the rains to points where it can seep into the substratum (Falcão, 1980).

It is difficult to determine which is the correct theory and most likely all have something to do with explaining salinity. Different factors could have been at work at different periods in the past as well as with varying degrees of importance at the present, in different parts of the region.

In addition to such general factors as climate, lithology and marine influence, there are other influences on the salinity of groundwater in specific localities. Poor circulation, or even stagnation, of groundwater can cause salinization to occur in crystalline areas. The flow of groundwater in these places is related to local conditions of topography. In hilly and mountainous areas, groundwater is of better quality, while in flatter and rolling areas, where there is less circulation of groundwater, a higher level of salinity is encountered (SUDENE, 1973, 1979). As highlands cover a minority of the Sertão, the second situation is the most common.

According to SUDENE (1973) the least saline groundwater is found in sedimentary areas where the level of salt is usually less than 500 mg/lt. Some isolated places have better groundwater, with a level of less than 100 mg/lt, while in others groundwater salinity can be higher, but it rarely exceeds 2000 mg/lt in sedimentary areas. Groundwater found in crystalline rock zones is highly saline. The salt concentration is usually above 2000 mg/lt and can exceed 28000 mg/lt

(SUDENE, 1974). As the greater part of the Sertão has a crystalline substratum this type of groundwater is most commonly encountered in the zone.

c) Groundwater Limitations for Irrigation

Despite the superior quality and greater quantity of groundwater encountered in the sedimentary areas of the Sertão, the practice of irrigation is rare in these places. One explanation is the great depths at which water is found. On average, it is located at a depth of 150 metres, and up to 300 metres in some places. Such deep wells are beyond the means of local farmers and only the government development agencies of the region have the appropriate equipment and capital to drill them. However, when deep wells are dug, the purpose is not for farming but rather for domestic needs in hamlets and towns. Otherwise, the lack of capital limits the development of well-based pump irrigation of the type which Bowden (1965) and Cantor (1967) describe for western North America.

Farmers of the Sertão use sedimentary groundwater when it wells up naturally to the surface under artesian pressure. These springs are called olhos d'água and are usually located at the foot of mountains. However, they are a rare phenomenon in the Sertão and a concentration of these springs in a single place only occurs in Cariri where it reaches a scale to encourage irrigation.

As crystalline zone groundwater is highly saline, well above the limit for cropping use, little of it can be used for irrigation. Only a few plants can tolerate higher amounts of salt but even with these there is the danger of long-term salinization of the soil. Ironically, crystalline zone groundwater is found at shallower depths, i.e. less than 40 metres on average and up to 90 metres at maximum.

However, it is difficult and expensive for local farmers to locate these deposits because they tend to be dispersed in fissures and fractures. While this water might not be very good for irrigation it can be utilized for animals and some domestic purposes, but often it is too saline for drinking water, the limit of which is 4000 mg/lt (Falcão, 1980; SUDENE, 1973).

The groundwater most often utilized for irrigation is that found where alluvial soils are deposited over a crystalline substratum. Despite the fact that these soils are only encountered in 5% of the crystalline zone, this groundwater has historically been the most important source in the Sertão. It is usually found at shallow depths and is easy to extract. Even after the interruption of the flow of a river during the dry season, it is still possible to find water in the river bed and on the edge of rivers, either in natural or excavated springs. However, the overall amount of water is still not abundant. SUDENE (1973) estimates the quantity to be 2×10^9 m^3 per year which is an insignificant volume of water given the territorial dimensions of the Sertão. In addition, MINTER (1973) and SUDENE (1974, 1979) point out that when this water is located at a depth of three metres or less it can become saline due to contact with salt that accumulates close to the soil surface. At the same time, groundwater salinity varies seasonally and can often be used during at least part of the year.

It can be concluded that the groundwater of the Sertão is usually not suitable for irrigation cropping, both for reasons of limited quantity and poor quality. At present, irrigation is practised almost exclusively with surface water from rivers and from reservoirs. Nevertheless, limitations in the use of this kind of water are also encountered for it too is not always abundant or of good quality.

Surface Water

With the exception of the São Francisco River, all other rivers of the Sertão are seasonal. Larger seasonal rivers flow for several months, but usually never more than six months, while small rivers only flow for a few days at a time when actual rainfall occurs.

Irrigation is only possible along rivers where sufficient water is available for a length of time corresponding to at least the crop cycle. For most short-cycle crops of the zone, such as beans, maize, onions, melons, tomatoes and watermelons, this means that water must be available for three to four months. Most Sertanejo rivers do not have such a sufficiently large flow or volume of water to irrigate on a large scale, so that some sort of storage facility is needed. Problems with water quality are also important. All too often this is often overlooked with the result that some public reservoirs have been constructed whose water is too saline for irrigation or any other purpose.

a) Quantity of Water

Sertanejo rivers are of an intermittent and torrential nature, which is related to the concentration and irregularity of rainfall, to the low permeability of soils and to the existence of a crystalline substratum in most places. These features together make it difficult for water to infiltrate into the ground, favour rapid surface run-off and thus contribute to violent flooding, which, in turn, is quickly followed by a sharp drop in the discharge of the rivers to the point that most are completely dry for much of the year (MINTER, 1973; SUDENE, 1974, 1979; Nimer, 1977; 1979; Stefan, 1977).

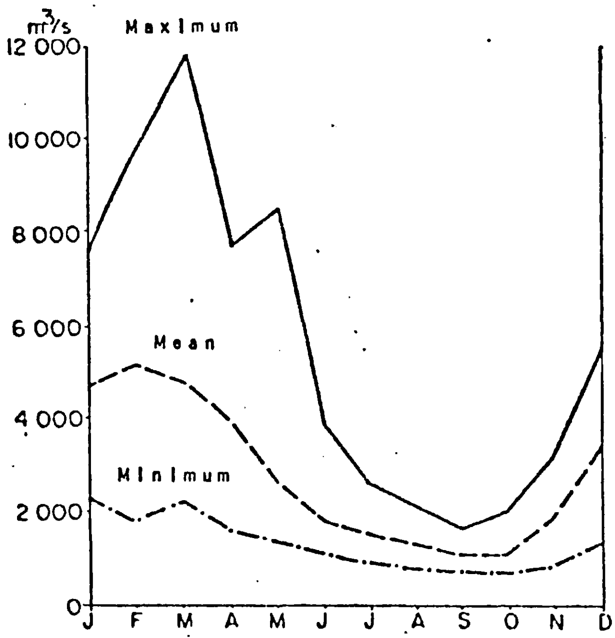
The average discharge of Sertanejo rivers is only 3 lt/sec/km and during the course of a year the period of zero discharge is always longer than that of actual river flow. More than 80% of the rivers are completely dry for an average of seven to eight months of the year (Nimer, 1979). They may flow during four to five months, but volume is insufficient for irrigation.

Sedimentary areas have higher discharge rates than do crystalline areas but even there rivers are completely dry for the greater part of the year. In sedimentary areas, the average time for a decrease in discharge from 10 to 1 m/sec is 86 days, varying from 43 to 175 days, while in crystalline zones the average period is 36 days, varying from 33 to 49 days (SUDENE, 1974, 1979; Nimer, 1979).

Sertanejo rivers can be classed into four types on the basis of discharge and period of flow: large perennial, large seasonal, medium seasonal, and small seasonal rivers. The São Francisco River is the sole example of the first type. The Jaguaribe and Açu/Piranhas Rivers are the only examples of the second type. Medium seasonal rivers are more common in the Sertão of which the largest tributaries of the São Francisco and Jaguaribe are examples. Most water courses are of the small seasonal type. With the exception of the large seasonal rivers, all are found in the study area.

The São Francisco River is often considered to be the most important river of the Sertão because of its perennial nature, but this also makes it an atypical river in the zone. SUDENE reports that the average discharge at Juazeiro for the period 1929-1968 was 2799 m^3/sec, varying from an average minimum of about 700 m^3/sec to an average maximum of about 12000 m^3/sec (Figure 9).

São Francisco River
(1929-1964)



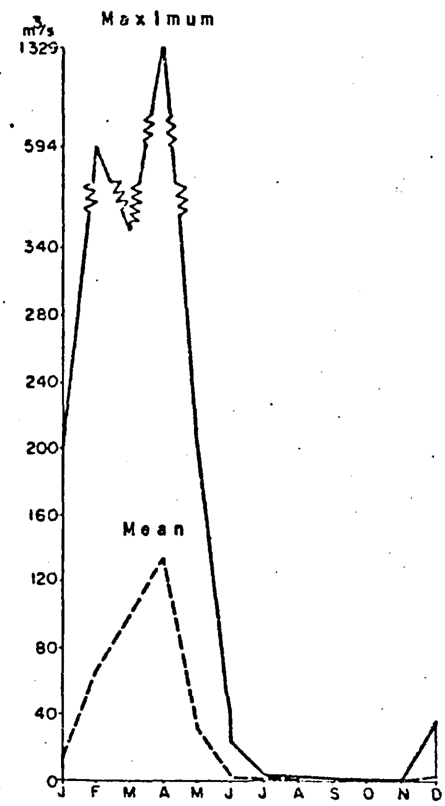
Source: Steffan (1977).

Figure 9. Average Monthly Discharge of the São Francisco River.

Despite the fact that the volume of water flowing in the São Francisco diminishes enormously from the rainy to the dry season, water for irrigation is still plentiful throughout the year. The IR-8 variety of rice, for example, has one of the highest water requirements, 17000 m^3 for a relatively long harvest cycle of five months (EMBRAPA, 1976), yet the amount of water available in the river over the year would be enough to irrigate more than four million hectares of rice. To date, the amount of irrigation and other uses of water along the river have not even begun to deplete the water supply, as Heathcote (1983) and Sheridan (1983) report occurred for the Colorado River in western North America.

A second kind of Sertanejo river is the large seasonal type exemplified by the Jaguaribe and the Açu/Piranhas. These rivers flow for longer periods of the year than do most Sertanejo rivers and can run up to eight months (Figure 10). However, outside the use of reservoirs, year-round irrigation is rarely possible because sufficient water is only available for about five months of the year.

Jaguaribe River
(1912-1964)



Source: Steffan (1977).

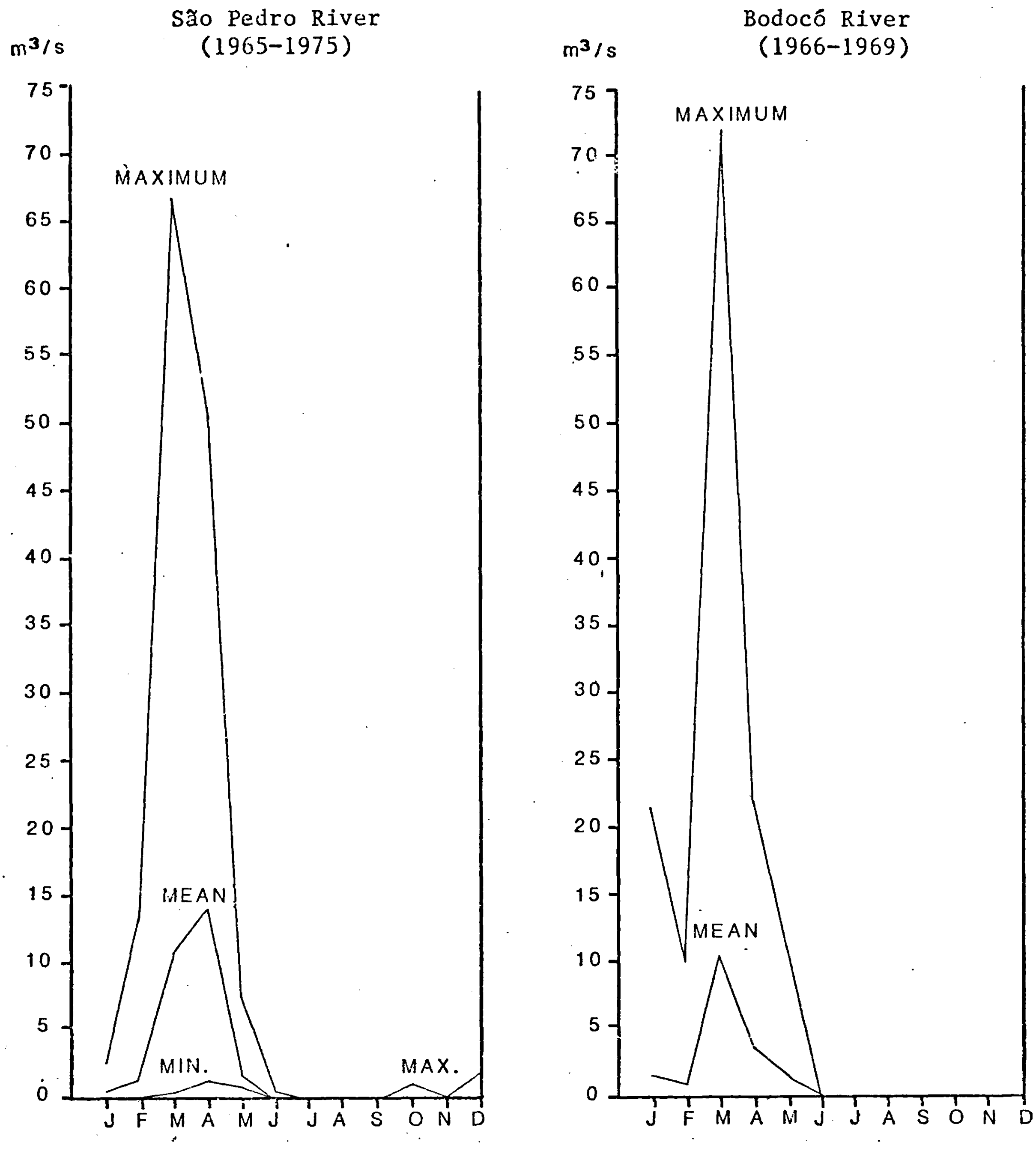
Figure 10. Average Monthly Discharge of the Jaguaribe River.

The main tributaries of the São Francisco and Jaguaribe fall into the third type of Sertanejo rivers. The supply of water is more restricted and the irrigation practised is much smaller in scale. The Brígida River, a tributary of the São Francisco which is located in the northern half of the study area, can be considered a typical medium-sized seasonal river of the Sertão. It usually flows for five to six months of the year but the flow is not continuous.

Fluvial information on the whole Brígida system is not available but SUDENE has data on two of its principal tributaries which occupy about three-quarters of the basin. The Bodocó River had a mean discharge of 2.2 m^3/sec during the months of river flow for the period 1966-1969 and the São Pedro River had a mean discharge of 4.5 m^3/sec during the months of flow for the period 1965-1975 (Figures 11 and 12). If all this water could be used for the irrigation of the four-month traditional variety of rice (which needs about 13600 m^3 of water) and if the rivers flowed long enough for the crop cycle, about 1460 hectares and 3570 hectares could be exploited respectively on each. However, not all the water can be utilized for irrigation and the rivers often only flow long enough for one harvest of short-cycle crops.

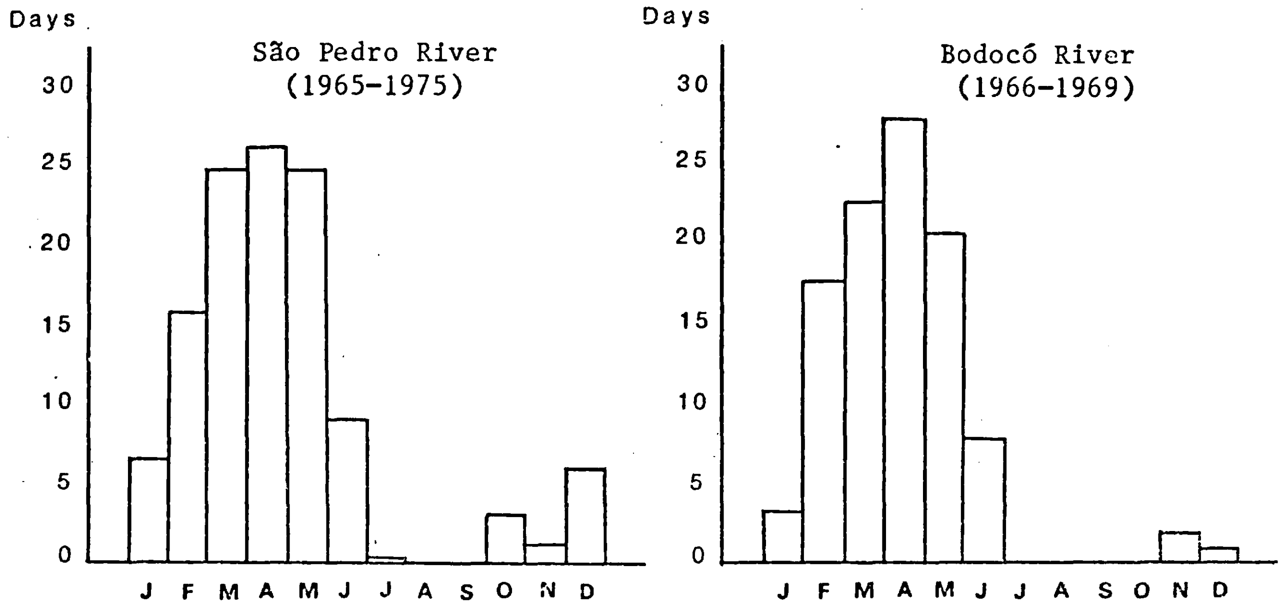
After the Brígida goes dry, natural springs provide some water for irrigation during the rest of the year. A few small dams are also found along the river and their water is utilized for irrigation. Indeed, most of the irrigation practised on this river is found only where there is a spring or a dam. The reason for this is that during the peak of the rainy season not much irrigation can be undertaken. At this time heavy precipitation and flooding can destroy much of the work done in preparing the land and the heavy clay soils, when overly wet, are too mucky to work. Furthermore, many irrigation crops are very sensitive to humidity and less rainfall is better for their development. Hence, at most, three months of river flow can be used for irrigation which is too short a period for many of the crops used.

The Macururé River and the Várzea River, which are Bahian tributaries of the São Francisco River and located in the southern part of the study area, are good examples of smaller seasonal rivers of the Sertão. No fluvial data is available for this type of river. Local farmers say, and the researcher observed, that the rivers normally flow for only a few days a month during the short rainy season. Under these conditions, without a means of storing water, it is not possible to irrigate even the shortest cycle crops. Several springs exist in the Macururé River but only one was being used for irrigation at the time of the field work. Otherwise, irrigation is only used when reservoir water is available.



Source of Data: SUDENE.

Figure 11. Average Monthly Discharge on the São Pedro and Bodocó Rivers.



Source of Data: SUDENE.

Figure 12. Average Number of Days of Discharge on the São Pedro and Bodocó Rivers.

As most Sertanejo rivers normally do not provide enough water throughtout the year, the construction of reservoirs is, therefore, essential for supplying water for irrigation. However, considerable debate exists about the type of reservoirs that should be built in the Sertão. The focal point of contention concerns reservoir size. Are large or small reservoirs more appropriate for the Sertão?

Those who are in favour of the construction of small and medium dams argue that this type of reservoir can be built in most places and can attend to the needs of a large number of farmers (Duque, 1980). Based on research done in the Jaguaribe basin, SUDENE/ASNIC (1967) found that water is available for two small reservoirs (of a barrage height of two to five metres) per 10 km^2. The reservoirs could, in turn, be fed by medium size dams located further upstream.

Although personnel from regional planning agencies suggest the above line of action, the federal government, through its agencies DNOCS and CHESF, prefers large reservoirs. While one publication of

SUDENE (1979) questions, if timidly, the policy of large reservoirs, the definitive government plan for the development of the Sertão (MINTER, 1973) tries to technically justify the large reservoir policy for public irrigation projects.

Most national and regional planners prefer large dams because they have the mentality that bigger is better. Furthermore, as Hall (1978) and Hoefle (1985) have shown, bureaucratic and political careers are measured by the size of public works undertaken while in office. Hence, in terms of stored water capacity, huge reservoirs have been the rule (Table 22).

Table 22. Size of DNOCS Reservoirs Located in the Sertão.

Size	Water Capacity	Reservoirs		Stored Water	
	1000 m^3	Number	%	1000 m^3	%
Small	< 5000	143	56.1	219 108	1.9
Medium	5 000 - 25 000	63	24.7	797 985	6.8
Medium-large	25 000 - 100 000	31	12.2	1 460 063	12.4
Large	100 000 - 500 000	10	3.9	2 252 300	19.1
Very large	> 500 000	8	3.1	7 035 360	59.8
Total	-	255	100.0	11 764 816	100.0

Source of Data: Guerra (1980).

The enormous Orós reservoir (Ceará) holds an incredible 2100 million m^3 of water, and plans exist to expand it to 4000 million m^3. Similarly, the Banabuiú reservoir (Ceará) holds 1000 million m^3 of water, the Poço da Cruz reservoir (Pernambuco) 504 million m^3 and the new Amado R. Gonçalves reservoir (Rio Grande do Norte) holds 2400 million m^3. If hydro-electric reservoirs are included, the largest in the world, which was proudly proclaimed at its inaugeration, is Sobradinho, located just upriver from Juazeiro and Petrolina on the São Francisco River. This reservoir covers more than 4000 km^2 of area.

The construction of large reservoirs has been soundly criticized because they concentrate enormous quantities of water in a single place, cover large areas of fertile land that are normally only found along rivers and only serve a restricted number of farmers who by chance own land on the edge of a reservoir or participate in a public irrigation project. The eight very large reservoirs alone contain almost 60% of the regional total of stored water. Meanwhile, the greater part of the Sertão continues to suffer from the traditional problems of seasonal water shortages every year and periodic drought (Bicalho & Hoefle, 1979; Hall, 1978).

The Orós reservoir is a typical example of such concentration of water resources. Some of the water goes by 20 kilometres of aquaduct to the DNOCS Lima Campos irrigation project in Icó but this only involves 2376 hectares of irrigation. In the last few years DNOCS has been forced to release some of this horde of water in order to allow a trickle of flow in the Jaguaribe River during the dry season. This was loudly proclaimed to have 'perennialized' the river.

There are two kinds of reservoirs constructed on medium and small seasonal rivers. DNOCS can publicly finance and build a medium or large reservoir in the main stream of the river in question. Alternatively, farmers build small rock and cement flow-over barrages in the main stream or they construct earth dams on secondary tributaries. They do this with either their own resources or more commonly, with bank loans.

Loans have enabled most medium and some small farmers to build small earth reservoirs, while in the past only the wealthiest of ranchers could construct a reservoir. However, building a dam is a risky business because flash floods frequently wash earth dams away. Of the ten interviewed farmers in the northern part of the study area who possess a barrage four of them had a dam break at one time or other.

Small rock and cement dams are increasingly being built in the northern part of the study area on the Brígida River and Terra Nova Rivers. Modest amounts of water are stored, about 100,000 m^3, but the water remains within the river channel and does not inundate scarce bottomlands like larger reservoirs do. Instead of one large reservoir being associated with a complex system of aquaducts and distribution canals, a series of small barrages are built along a river and farmers draw water directly from the reservoir in front of their fields. This does not require expensive engineering works and funds could be available for adopting such a system throughout the Sertão.

Reservoirs are more rarely encountered in the southern part of the study area in Bahia State. The causes for this are environmental, economic and political. Rivers only flow for a very short time there and violently when they do. The flat terrain also makes the construction of reservoirs difficult. Some sites could be utilized for small dams but farmers of the area are too poor for such costly investments. Finally, farm credit is not readily available in this area due to the scarcity of banks and lack of government interest. Some of the existing reservoirs were created with the construction of a high bank highway (since abandoned) through the area. These reservoirs are beyond the means of local farmers and they favour those who by chance have land on the reservoir edge. It is exactly these farmers who are introducing irrigation into the area.

b) Quality of Water

Besides the availability of surface water, one must also consider the water quality for irrigation purposes and with special reference to salinity. Very little of the surface water of the Sertão is free of salt, and most of it, when utilized in irrigation, requires careful control in order to avoid soil salinization. The general considerations that are used to explain the poor quality of the groundwater of the Sertão are also relevant for explaining the poor quality of surface water. High rates of evaporation, the presence of crystalline rock formations and soil salinity can all cause the salinization of surface water. Reservoir water is probably the most problematic. Reservoirs present a large surface of exposed water and if water lies stagnant, high rates of evaporation raise its salinity.

The quality of river water in the Sertão does not receive much attention from the regional planning agencies. Records are available only for a few large rivers that are considered to be important but these are not typical Sertanejo rivers. The same happens with reservoirs. Records are available for larger reservoirs and not for smaller ones. It seems that the agencies are more interested in the volume of water than in its quality. However, judging water quality is just as important as considering the volume available, precisely because not all Sertanejo water is adequate for agriculture.

One of the best ways to judge the quality of irrigation water is to use the relation between electrical conductivity and the sodium absorption rate (SAR) as suggested by USDA (1953). Unfortunately, information for the SAR measure is not available for the Sertão. So the analysis here relies exclusively on electrical conductivity, which still gives a reasonable indication of salinity (Table 23). Even conductivity measures of water in the Sertão are hard to come by and those presented here are about all that are available.

According to SUDENE (1973) water considered excellent for irrigation is that which has less than 160 mg/lt of salt. Water up to 480 mg/lt of salt is still considered good. Water containing more salt than this and up to 1440 mg/lt of salt is classified as being only fair for cropping, but SUDENE holds that it can still be used. Above this limit, water is considered poor for irrigation and should not be used in order to avoid soil salinization.

Table 23. Irrigation Water Salinity Classification.

Electrical Conductivity (micro mhos/cm 25°C)	Dissolved Salt (mg per litre)	Level of Salinity	Crop Tolerance
<100	<64	free	little effect
100 - 250	64 - 160	low	sensitive crop yields affected
250 - 750	160 - 480	medium	most crop yields affected
750 - 2250	480 - 1440	high	only tolerant crops yield satisfactory
>2250	>1440	very	a few very tolerant crops yield satisfactory

Source of Data: Falcão (1980), USDA (1953), Withers & Vipond (1974).

Falcão (1980), USDA (1953) and Withers & Vipond (1974) are more discriminating than SUDENE in terms of what water can be used safely for irrigation. While SUDENE accepts water with up to 480 mg/lt of salt for use in irrigation with little restriction, Withers & Vipond and Falcão hold the view that medium levels of salt are present when electrical conductivity readings of 250-750 micro mho/cm (the equivalent of 160-480 mg/lt) are registered, and that the yields of most crops will be adversely affected. Above 480 mg/lt of salinity, only plants which have great tolerance for salt can be irrigated and only in highly permeable soils. Most soils of the Sertão are of the low permeability type as SUDENE (1973, 1974, 1979) itself points out. Hence, when judging the quality of water, SUDENE should be less eager to promote irrigation at any cost through the use of poor quality water and should rather consider the long-term consequences of such unrestricted use.

As the São Francisco River is considered to be the most important river of the Sertão the quality of its water has been well studied. The quality of the water was found to be the best for agricultural purposes in the zone, being practically salt free. Electrical conductivity measures taken by DNAEE in different months of the year during the period 1977-1981 never registered readings superior to 135 micro/mhos and the average is 92 micro/mhos.

The electrical conductivity of seasonal rivers is much higher. The readings for the large seasonal Jaguaribe River were on average 359 micro/mhos for the period of 1977-1980. No data are available for small seasonal rivers but the tributaries of the Jaguaribe serve as examples of medium-sized seasonal rivers. Electrical conductivity readings taken on these rivers are of a similar scale to the main stream Jaguaribe or higher. During the period 1977-1979, readings averaging 350 micro/mhos were taken by DNAEE on the Salgado River, and in 1978, readings averaging 519 micro/mhos were taken on the Banabuiú River. In general, the river water of the Jaguaribe basin is of medium salinity and caution should be exercised when using it for irrigation. Indeed, as yields can be reduced over time when utilizing water of medium salinity, the point might be reached where the yields obtained may not compensate for the high costs involved in the irrigation.

Unfortunately, with the exception of the São Francisco River, there are no official data available concerning salinity for the rivers of the study area. During the course of the field research undertaken in 1981, some water samples were collected and analyzed (Table 24).

Table 24. Water Salinity in the Study Area.

River and Local	Number of Samples	Sample Source(a)	Mean EC(b)	Salinity Level
Brígida				
Parnamirim	28	springs & dam	2251.4	very high
Custódia				
Custódia Project	4	irrigation canal	535.0	medium
Salgueiro				
Boa Vista Project	12	irrigation canal	442.9	medium
São Francisco				
Belém do S.F.	14	river	100.4	low
Bebedouro Project	8	irrigation canal	103.8	low

Source of Data: Field Research.

(a) Water samples were collected during October and November 1981. This was in the dry season and three years into a drought.

(b) Electical conductivity (micro/mhos at 25°C)

The samples for the São Francisco River were drawn from the main irrigation canal of the CODEVASF Bebedouro project near Petrolina and directly from the river in Belém do São Francisco further downstream. The results show a low rate of salinity in both places similar to those found by DNAEE.

The Brígida River was already dry when field work was carried out in 1981. While it was not possible to sample the flowing water, samples were taken from two springs and a small dam. The electrical conductivity readings for this water averaged 2251 micro/mhos, which signifies that a very high amount of salt is present in the water.

The rivers in the southern part of the study area were also dry during the period of field research of 1981, so it was not possible to sample their water. Given the physical conditions of the area, river water there must be some of the most saline in the Sertão. According to local farmers, the Macururé River is extremely saline through its entire course and the Várzea River is saline from the middle of its course downstream. Moreover, layers of salt are clearly visible on the surface of the dry river bed of the Macururé River (Plate 5).

Plate 5. Visible salt deposits in the river bed of the Macururé River (Chorrochó County, 1979).

The problem of rising salinity of reservoirs is an old one. The Cedro reservoir at Quixadá in Ceará State was the first large reservoir to be built in the Sertão by the federal government. With time it was rendered virtually useless because the water turned saline and the irrigation works were abandoned.

The electrical conductivity readings of public reservoirs show that salinity is fairly high in most of them but it is not possible to know exactly, because information is not given concerning sampling methods (Table 25). The data are from a single study done over thirty years ago and nothing new has been published since. If we assume that the sample is representative, the great majority of the reservoirs have a medium level of salinity and their water must be utilized with care for irrigation.

Table 25. Quality of the Water in Sampled Public Reservoirs in the Northeast (1950-53).

Level of Salinity	Number	%	Mean Electical Conductivity (micro/mhos)
High	2	11.8	1445
Medium	11	64.7	418
Low	4	23.5	195
Total	17	100.0	486

Source of Data: Pioger, R. cited in SUDENE (1979).

In the field, reservoir water was sampled in two DNOCS irrigation projects of the study area. The water being used for irrigation on the Boa Vista project had an average electrical conductivity reading of 443 micro/mhos and that of the Custódia project 535 micro/mhos (Table 24). The water of both are well into the medium range of salinity and special care should be observed to maintain crop productivity.

Not only are adverse environmental conditions to be blamed for reservoir salinity. All too often DNOCS is under political pressure to store as much water as possible or to merely undertake public works in specific places even if the merits for locating a reservoir there are dubious. Studies prior to construction are usually made of flooding potential so as to avoid dams being carried away but the long-term quality of the water to be stored is given scant attention.

Two huge reservoirs are in construction in the Brígida basin. One of the prime forces in the construction of the dams is the pressure of an important politician who has complained that a large reservoir has not been built in Pernambuco State in ten years. Given the high salinity of water in the system, not only will enormous areas of valuable bottomland be inundated upstream but large tracts will be salinized downstream. On the neighbouring Terra Nova system, salt was observed seaping under the medium-sized Abóbora public reservoir and ruining or adversely affecting crop productivity up to twelve kilometres downstream.

Steffan (1977) has shown how the non-renewal of reservoir water under the climatic and geological conditions of the Sertão leads to the salinization of the large public reservoirs. The stagnation of water in reservoirs also causes the settling of sediments to the bottom so that water drawn for irrigation is nutritionally poor for plants. This author defends the use of a series of small barrages of the type which permit flood water to flow freely over the dam in such a way as to permit frequent renewal of the stored water. Such a system represents a more appropriate technology for storing water in the Sertão and has advantages in terms of water quality.

c) Water Supply and Irrigation Technology Level

Both in the study area in the whole Sertão, a strong relationship is observed between the availability of water and irrigation technology level. Access to a perennial source of water or to one which lasts for the greater part of the year allows the use of more industrial inputs. Conversely, more labour-intensive forms of irrigation are found in places which experience a shortage of water.

The supply of water acts as a limiting factor for the expansion of irrigation. Cultivating a small area may not always be profitable when more industrialized inputs are utilized. So, the scale of irrigation, in turn, also influences a farmer's choice of technology type, and the interplay of the factors of limited water supply and scale sets up a pattern which does not encourage the adoption of a more capital-intensive technology.

The perennial character and the high discharge of the São Francisco River are the chief reasons for explaining the emergence of modern irrigation along its course. Large areas can be cultivated throughout the year and multiple harvesting is possible. The abundance of water has allowed for an increase in the scale of production to the point where techniques involving larger quantities of capital can be used, which in turn, further increase the intensity of land use.

A good amount of water is available on the lower reaches of the large, seasonal Jaguaribe and Açu/Piranhas Rivers and these are important irrigation areas. However, private-sector irrigation practised on these rivers does not reach the scale attained on the São Francisco so that the technology utilized is usually labour-intensive or of the low intermediate type. On the medium and small seasonal rivers of the Sertão, the scale of irrigation becomes progressively more restricted and dry farming activities assume greater importance.

A good deal of variation in private-sector irrigation technology is observed in the study area, and the influence of water availability and of scale in the capital intensity of irrigation is clearly seen (Tables 26 and 27). More than 39% of the farms on the São Francisco River irrigate more than 30 hectares during the year, and more than half use a high intermediate or capital-intensive technology. At the other extreme, on seasonal rivers with no water storage facilities, about 86% of the farms irrigate less than five hectares and all use a labour-intensive or low intermediate technology type.

More water is available on the tributaries in the northern part of the study area. On the Brígida River, one finds labour-intensive as well as intermediate technology irrigation practised and this is strongly related to the availability of water. Those farmers who possess springs and dams on their land have water for a longer time during the year, and they plant larger areas. Some plant two harvests per year and use more industrial inputs than those who only have water during the normal period of river flow. Much less water is available on the tributaries in the southern sector of the study area and irrigation is restricted to a few farmers planting a hectare or two. With the exception of one large fruit farm, the small amount of irrigation that can be practised there is of a labour-intensive or low intermediate type.

Table 26. Size of Irrigated Area on Private-Sector Farms according to Source of Water.

Irrigated Area	São Francisco River		Perennial Reservoir		Seasonal River with Springs or Seasonal Reservoir		Seasonal River	
	n	%	n	%	n	%	n	%
<5 ha	8	17.4	5	45.4	4	50.0	6	85.7
5-10 ha	8	17.4	2	18.2	3	37.5	1	14.3
10-30 ha	12	26.1	3	27.3	1	12.5	0	0
>30 ha	18	39.1	1	9.1	0	0	0	0
Total	46	100.0	11	100.0	8	100.0	7	100.0

Source of Data: Field Research.

Table 27. Irrigation Technology Level on Private-Sector Farms according to Source of Water.

Technology Level	São Francisco River		Perennial Reservoir		Seasonal River with Springs or Seasonal Reservoir		Seasonal River	
	n	%	n	%	n	%	n	%
Labour-intensive	2	4.4	3	27.3	2	25.0	4	57.1
Low intermediate	20	43.5	3	27.3	5	62.5	3	42.9
High intermediate	14	30.5	5	45.4	1	12.5	0	0
Capital-intensive	10	21.7	0	0	0	0	0	0
Total	46	100.0	11	100.0	8	100.0	7	100.0

Source of Data: Field Research.

Public-sector irrigation projects are invariably capital-intensive by plan but this does not mean that technology level is unrelated to the availability of water. On the contrary, the projects are purposely located along perennial sources of water, such as the São Francisco River or near big government reservoirs, so that large-scale, capital-intensive irrigation can be undertaken. Indeed, a number of very large reservoirs are being enlarged so as to provide yet more water for the projects. This necessity for large amounts of water obviously restricts the number of sites where public-sector irrigation can be practised and, indeed, limits the role of government in promoting the diffusion of irrigation to typical Sertanejo farming zones.

SOILS RESOURCES IN THE SERTÃO

Soil is a very important natural resource for agriculture, including irrigation agriculture. As Withers & Vipond (1974) note, the objective of irrigation is to guarantee the supply of water to crops but this is not a simple process of merely watering plants. A complex relationship of land, water and climate is involved. Soil not only nourishes crops but is also a medium through which water must pass to reach the crops and in which precious moisture is conserved or lost.

For irrigation, soils must be of a type that hold a specific amount of water for a period of days in order to supply plant roots with a constant degree of moisture. Water must not drain too fast nor should large amounts of it be held at the surface for too long. The correct control of soil humidity in irrigation is of paramount importance for avoiding water logging and salinization. This is especially true for arid environments where soils are of low fertility, of poor permeability, of deficient drainage capacity and contain concentrations of salts; these factors all increase the risk of salinization when irrigation is used (Amiram, 1970; Russell, 1973; Thorne, 1970; Withers & Vipond, 1974).

The environmental conditions of the Sertão tend to be of the arid type and studies have found the soils of the zone to be generally poor for agriculture (Duque, 1980; EMBRAPA, 1972/73, 1977/79; MINTER, 1973; SUDENE, 1973, 1974, 1979). Besides problems with fertility, permeability and drainage conditions, it is also common for these studies to note the negative influence of slope, of sparse vegetation and low soil moisture.

Usually the scarcity of water has been viewed as the most formidable limitation for a more intensive use of Sertanejo lands (Duque, 1980; EMBRAPA, 1972/73, 1977/79; MINTER, 1973; SUDENE, 1973). Following this line of thought one would conclude that irrigation is the most appropriate form of agriculture for the Sertão because, with its practice the water supply problems can be overcome. However, even if water were plentiful, most Sertanejo farm land is not suitable for irrigation and for many of the problems cited above.

General Soil Types of the Sertão

Soil surveys of sufficient detail for estimating the amount of land in the Sertão that is suitable for irrigation are not available so that only a broad overview of the main soil types found in the region can be provided here. Moreover, the vague description of soils in the EMBRAPA and SUDENE studies means that the analysis will be restricted to making a few general comments concerning the appropriateness of irrigation for these soils.

There are five main types of Sertanejo soils: latosols, podzols, non-calcareous brown soils, lithosols and quartz sandy soils. These soils can be encountered in association with one another in some places and can be found in isolated form in others. A number of other soil types have been identified locally or in combination with the main types but these do not cover extensive areas. Among the latter soils, it is only relevant to discuss the alluvial soils, which are those most used for irrigation. The following description of the various soil types is based on the soil studies of EMBRAPA (1972/73, 1977/79) and SUDENE (1973). Most of the interpretation is based on Russell (1973), USDA (1951, 1953) and Withers & Vipond (1974).

There are four kinds of latosols in the Sertão: yellow-red, dark-red, eutrophic yellow-red and eutrophic dark-red. In general, they are deep soils, of sandy and porous character. They are usually found in sedimentary areas and are strongly weathered throughout. Low levels of natural clay are present, with little variation in the total content from surface to deep horizons. Chemically the soils are poor, have a low cation exchange capacity and are acidic.

As these soils drain rapidly, they require large amounts of irrigation water, while considerable amounts of fertilizer are needed to overcome their low fertility. Hence, their use for irrigation may not be economic.

Three types of podzols are found in the Sertão: yellow-red, eutrophic yellow-red and plinthic yellow-red. These soils are of medium texture and have deep to very deep profiles of the A-B-C type. The B horizon has a high proportion of natural clay, which is poorly flocculated. Chemically, the soils are acidic or slightly acidic, have low to medium fertility, and possess low levels of excheangable bases.

While these soils are better for irrigation than are the latosols, they are still not good for agriculture. The acidity needs correcting and fertilizers are required to overcome the low natural fertility. Furthermore, when a highly clayey B horizon is present, drainage problems can arise and salinization can occur.

Non-calcareous brown soils of the Sertão are shallow to moderately deep soils of the A-B-C type. The texture of these soils is fine to medium. Subangular and angular blocks with vertical cracks are encountered, especially during the dry season, as a result of the presence of montmorillonitic clays. Chemically, these soils are fertile and well endowed with exchangeable bases.

For agricultural use, these soils appear to be the best in the interfluvial areas of the Semi-Arid Zone. They are naturally fertile but their high clay content makes them hard to till and often they can only be worked with a tractor. While their fine texture aids the retention of water in the soil, this trait also makes water absorption by plants more difficult. When irrigated, their clayey character makes for poor drainage and hence increases the risk of salinization. Moreover, the low calcium reserves of these soils poses the threat of alkalinization, i.e. the replacement of calcium ions by sodium.

Lithosols are widely distributed throughout the Sertão. These soils usually have an A-R type profile with the A horizon found directly on top of bedrock. At times an intermediate C horizon or an incipient B horizon may be present. Texture is variable from sandy to clayey and fertility varies from low to high.

This characterization of lithosols is vague, to say the least of it, but the shallowness of these soils means that they are not very suitable for cropping. At the most, lithosols can provide shrubby native pasture for extensive stock-raising.

Quartz sandy soils of the Sertão are deep to very deep soils. Most are acidic and possess very low fertility. They drain exceedingly fast and have an extremely low capacity to retain moisture and soil nutrients. While an accumulation of colloids can occur at deep levels, these are dispersed and do not form proper horizons.

These soils are not suited for cropping of any type, least of all for irrigation. At present they merely serve as pasture for seasonal extensive stock-raising and even then only during the rainy season.

Depositis of alluvial soils are only found in significant quantity along the largest rivers of the Sertão. Nevertheless, all seasonal water courses have deposits of such soils. Historically, most Sertanejo cropping has been carried out in these lands and they are popularly called baixios and várzeas. These soils are usually poorly developed and are merely a series of superimposed layers. Texture can vary from medium to fine.

When high amounts of clay are present, drainage problems can arise and the soils can be hard to work. Also, as the land is low laying, solodic solonetzs tend to occur, which poses a serious risk of salinization when irrigated.

Irrigated Soils of the Study Area

All of these soil types are found in the study area. Alluvial soils, podzols and quartz sandy soils are found along or near rivers in the area. Latosols, non-calcareous brown soils and lithosols are usually encountered in interfluvial zones. Of the interfluvial land, non-calcareous brown soils and latosols are the only soils which could be used for irrigation and occur extensively. However, neither show much potential for irrigation, latosols due to problems of acidity, fertility, slope, & texture and non-calcareous brown soils due to difficulties with alkalinity, slope & texture. The practice of irrigation is, therefore, normally restricted to land located along rivers.

Most irrigation along the São Francisco River is undertaken on alluvial land. The width of alluvial soils inland varies from place to place, from tens of metres to a couple of kilometres or more. The numerous islands on the lower-middle São Francisco River represent important deposits of this type of soil and some of them are quite large, e.g. the Ilha Grande covers 1700 hectares and the Ilha da Várzea 1620 hectares.

These soils are little developed. Only the A horizon is defined, with mixed sandy layers occurring below. The soils have a high base saturation of 60% or more, are neutral to moderately acidic, have moderate to rapid permeability and are very well drained. Relief is flat with occasional small depressions and slope is 3° at most so that erosion is not a problem and conditions are favourable for mechanization. However, solodic solonetz soils make up 30% of the composite alluvial soil. The solodic solonetz are of an indiscriminate texture and are usually concentrated in low laying places where salt can accumulate (EMBRAPA, 1972/73). The presence of the solonetz soils should be looked upon with certain alarm for it poses the threat of long-term salinization.

On CODEVASF projects along the São Francisco River, non-alluvial soils are used. The reason for this is not explained by questions of soil quality for irrigation but rather by long-term plans to build dams along the river. The old Petrolândia project will be lost to the Itapirica reservoir and other projected dams will inundate large stretches of alluvial soils. The soils used for irrigation are normally latosols and their poor quality adds to the problem of salinization on the CODEVASF projects.

Irrigation <u>on the tributaries</u> is also usually practised on alluvial soils. While these soils can be found along most water courses they are only encountered in significant quantities at certain points along the medium-sized, seasonal Brígida, the Pajeú and the Moxotó Rivers.

The alluvial soils of the tributaries are different from those encountered on the main stream. The tributary alluvial soils are highly structured clays. Moreover, they are commonly associated with high proportions of solodic solonetz and other halomorphic soils. The soils are moderately drained and permeability varies from moderate to low. Chemically, they are acidic, neutral or even alkaline depending on the place. Base saturation is high, commonly 90% or more (EMBRAPA, 1972/73).

While the alluvial soils of the tributaries are fertile their clayey nature poses drainage problems which, together with the medium to high presence of sodium in some areas, can lead to salinization. In addition, the heavy to very heavy consistency of the soils makes them hard and difficult to work. Farmers affirm that not even a tractor turns the soil unless the land has been wet first.

The Impact of Irrigation on Soils in the Study Area

Salinization and waterlogging are the two most intractible problems concerning soils for irrigation. For almost all the soils of the Sertão, waterlogging is not a common problem and salinization is the gravest concern. In order to analyze the impact of irrigation on soils of the study area, 244 samples were collected on farms in irrigated and non-irrigated soils. The investigation was meant to ascertain roughly the extent to which irrigation is associated with salinization.

The first objective of the soil analysis was to determine the seriousness of salinization. Another point investigated was to see whether salinization is worse in certain types of soil than in others. This is basically a comparison of the sandy soils found along the São Francisco River and the clay soils of the tributaries. A third aim of the study was to determine the influence of slope on salinization.

This is an important consideration because most Sertanejo lands are not flat and farmers do not have the necessary capital for levelling their land. Lastly, the use of industrial inputs and more intensive land use systems is considered to see if this affects the level and rate of salinization. The question of appropriate technology is crucial because salinization can lower productivity to the point where more expensive production schemes are not viable.

Soil salinity was determined in the field by electrical conductivity. A more accurate analysis would also include the sodium absorption rate (SAR) measurements but it was not possible to do this.

A problem concerning the interpretation of the results arose after the measurements were made in the field. The measurements were made using a 1:1 ratio of distilled water to soil but it was subsequently only possible to find a scale for interpretation in which the paste method is used. So it was necessary to establish a specific classification of soil salinity for the measurements made in the field (Table 28). This was done by examining the distribution of electrical conductivity measures with reference to farmers' comments concerning crop productivity. The scales found in Falcão (1980), USDA (1953) and Withers & Vipond (1974) were then modified to reflect the method utilized.

Irrigation was found to significantly raise levels of soil salinity, especially after the eighth year. Salinization occurs more rapidly and attains more serious levels in lands with soils which do not drain well, with steeper and concave slope and where more capital-intensive forms of irrigation are practised. These problems occur more frequently on the tributaries but they also effect irrigation along the São Francisco River.

Table 28. Irrigation Soil Salinity Classification.

Electrical Conductivity (micro mhos/cm at 25°C)	Dissolved Salt (mg per litre)	Level of Salinity	Crop Tolerence
< 300	< 192	low	yields of very sensitive crops restricted
300 - 600	192 - 384	medium	yields of many crops restricted
600 - 1200	384 - 768	high	only tolerant crops yield satisfactory
> 1200	>768	very high	only a few very tolerant crops yield satisfactory

Source of Data: Field Research.

a) Length of Irrigation Period

The number of years that a field is irrigated was found to be related to salinity. Salinization usually becomes a problem after eight years of irrigation but this can occur earlier depending on soil texture, slope and irrigation technology utilized.

To analyse the effect of the period of irrigation on soil salinization for private-sector irrigation along the São Francisco River, a partial correlation coefficient was used to remove the influence of technology type on the two factors. The number of years of irrigation and the level of soil salinity were found to be moderately correlated, $r_{xy.z} = 0.39$. The first few years of irrigation do not modify salinity in any significant way (Table 29). However, after eight years, salinity gradually rises and the yields of most crops fall. Farmers are aware of this process and if they have sufficient land they practise field rotation whereby they put a field of declining productivity into fallow.

The problem of salinization is more acute in public-sector irrigation, and electrical conductivity readings for equivalent periods of use are higher than those of private-sector irrigation. As will be shown below, capital-intensive technology is the cause of this, but project farmers also are not allowed to correct rising salinity by fallowing. The objective of the projects is to practise continuous cropping and the administrative personnel feel that any problems which appear can be resolved through the use of chemical corrective agents.

Table 29. Soil Salinity according to Years of Irrigation along the São Francisco River(a).

Years of Irrigation	Private Irrigation			Public Irrigation		
	No. Samples	Mean EC(b)	Level of Salinity	No. Samples	Mean EC(b)	Level of Salinity
none	52	267	low	12	116	low
2 - 3	20	194	low	-	-	-
4 - 7	-	-	-	-	-	-
8 - 10	24	326	medium	4	1809	very high
11 - 12	4	480	medium	12	743	high
> 12	20	590	medium	-	-	-

Source of Data: Field Research.

(a) Excluding samples from concave areas.

(b) Electric conductivity of 1:1 soil extract (micro mhos/cm at 25°C).

The impact of irrigation on soil salinity is worse on the tributaries (Table 30).[1] Initially soil salinity is low for both private and public irrigation. The sample for private-sector irrigation lacks fields with less than ten years of use but by this date very high readings were found for those farms sampled. Indeed, farmers complain of falling productivity and stunted crop growth. Stunted and discoloured crops and fruit trees were observed by the researcher.

The DNOCS Custódia project is an example where dramatic increases in salinity can occur quickly. The public-sector readings for two to three years are from this project. In the space of a few years will be shown below, capital-intensive technology is the cause of this, but project farmers also are not allowed to correct rising salinity by fallowing. The objective of the projects is to practise continuous cropping and the administrative personnel feel that any problems which appear can be resolved through the use of chemical corrective agents.

Table 29. Soil Salinity according to Years of Irrigation along the São Francisco River(a).

Years of Irrigation	Private Irrigation			Public Irrigation		
	No. Samples	Mean EC(b)	Level of Salinity	No. Samples	Mean EC(b)	Level of Salinity
none	52	267	low	12	116	low
2 - 3	20	194	low	-	-	-
4 - 7	-	-	-	-	-	-
8 - 10	24	326	medium	4	1809	very high
11 - 12	4	480	medium	12	743	high
> 12	20	590	medium	-	-	-

Source of Data: Field Research.

(a) Excluding samples from concave areas.

(b) Electric conductivity of 1:1 soil extract (micro mhos/cm at 25°C).

The impact of irrigation on soil salinity is worse on the tributaries (Table 30).[1] Initially soil salinity is low for both private and public irrigation. The sample for private-sector irrigation lacks fields with less than ten years of use but by this date very high readings were found for those farms sampled. Indeed, farmers complain of falling productivity and stunted crop growth. Stunted and discoloured crops and fruit trees were observed by the researcher.

The DNOCS Custódia project is an example where dramatic increases in salinity can occur quickly. The public-sector readings for two to three years are from this project. In the space of a few years salinity has shot up to very high levels. On the other hand, the soils of the older Boa Vista project attained a medium reading with ten years of use. Of all non-irrigated soils of the tributaries, those of the Boa Vista project were found to be the least saline and electric conductivity readings averaged 159 micro mhos/cm. This occurs because the initial soil salinity was very low and because the water used to irrigate is in the lower reaches of medium salinity. Ten years of use have only resulted in medium soil salinity on the project.

Table 30. Soil Salinity according to Years of Irrigation along the Tributaries(a).

Years of Irrigation	Private Irrigation			Public Irrigation		
	No. Samples	Mean EC(b)	Level of Salinity	No. Samples	Mean EC(b)	Level of Salinity
none	12	163	low	12	246	low
2 - 3	-	-	-	8	1295	very high
4 - 7	-	-	-	-	-	-
8 - 10	-	-	-	8	462	medium
11 - 12	8	2323	very high	-	-	-
> 12	16	1178	very high	-	-	-

Source of Data: Field Research.

(a) Excluding samples from concave areas.

(b) Electric conductivity of 1:1 soil extract (micro mhos/cm at 25°C).

These problems, combined with those of soil texture and the type of technology utilized, create a situation where irrigation on the tributaries must be practised with great care. This is an important point to make because conditions on the tributaries are similar to those of the rest of the Sertão while those along the São Francisco River are exceptional.

b) Soil Texture

Soil texture is another factor which was found to be important for explaining problems of salinization. Soils with higher clay content do not drain well and so pose the greatest danger of salinizing when irrigated (Figure 13).

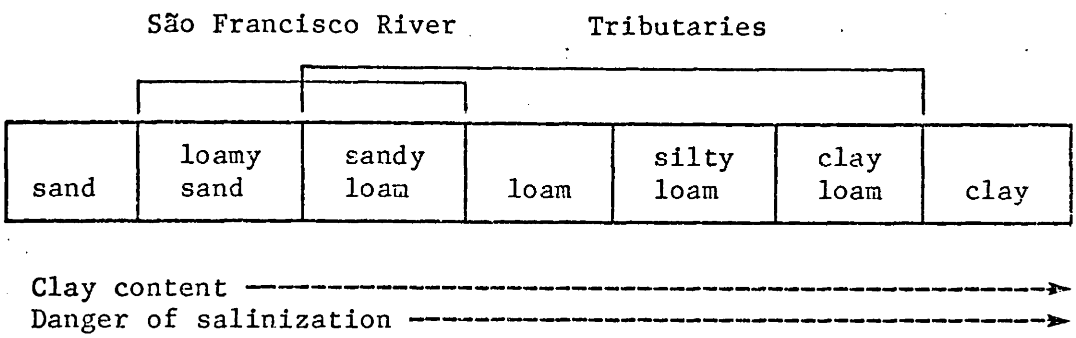


Figure 13. Soil Texture and the Danger of Salinization.

In this respect, the soils along the São Francisco main stream are better suited for irrigation. Most are sandy loam or loamy sand which allow for proper drainage yet do not let too much water escape to the sub-soil. The quality of water is good and occasional flooding helps to flush out salt and to lay fresh sediments over land closest to the river.

Of the 28 samples analysed for texture on private-sector farms, 73% were found to be sandy loams and the rest were loamy sands.[2] The non-irrigated EC readings of sandy loams averaged 235 micro mhos/cm which is a low level of salinity. When irrigated for more than eight years this rose to a lower medium level of 386 micro mhos/cm. Loamy sands were initially lower, with EC readings averaging 153 micro mhos/cm, but this rose to 392 micro mhos/cm after eight years of use.

The sample for the Bebedouro project was small but at least it gives an idea of what happens to irrigated soils in the public-sector.

Two non-irrigated loamy sand samples had a low mean EC reading of 149 micro mhos/cm. Three irrigated loamy sand samples had a high mean EC reading of 790 micro mhos/cm, while one sandy loam sample had a very high reading of 1287 micro mhos/cm. Therefore, despite the existence of fairly good soil conditions for irrigation to start with, public-sector irrigation along the São Francisco River is associated with high rates of salinization.

Soils of the tributaries are of the loamy type, containing more clay than those along the São Francisco River. Consequently, the hazard of salinization is greater there. Two non-irrigated samples from a private-sector farm on the Brígida River had a low mean EC reading of 132 micro mhos/cm, while the average for four irrigated samples was 1718 micro mhos/cm, which is a very high level of salinity. The lowest reading found for a single irrigated sample was 729 micro mhos/cm, which was for a better draining sandy loam soil. However, problems with salinity arise even in this soil type because of the highly saline irrigation water used.

All four of the samples from the DNOCS Boa Vista project are from sandy loam soils and the non-irrigated EC reading was 159 micro mhos/cm while the irrigated samples registered 462 micro mhos/cm. So in this type of soil salinity only rose from low to medium levels, possibly because of the good quality irrigation water used.

Various loamy soils were obtained from the DNOCS Custódia project. The EC reading of the non-irrigated sample was low, 237 micro mhos/cm, while the average of the irrigated ones was very high, 1965 micro mhos/cm. The single lowest reading for irrigated soils was 888 micro mhos/cm, again for a sandy loam.

One further set of four samples from Custódia, which was not included in the above averages, was collected in a completely salinized field. This field registered an incrediblely high average reading of 30410 micro mhos/cm. The field is not used and was the worse example of salinization encountered anywhere. It is located in a low laying area and the soil has turned black, visible white patches of salt have formed and the land never dries. This field and the other very high readings elsewhere demonstrate how dangerous it is to irrigate soils that are not appropriate for irrigation cropping. The most astonishing aspect of the Custódia project is just how fast salinization has occurred, in the space of only two to three years of use.

From this it is reasonable to conclude that only sandy loam soils should be used for irrigation cropping on the tributaries and even then with great care. Both irrigation and flooding deposit salt from highly saline river water in the soil and it remains there because of poor drainage. Layers of salt build up in the sub-soil and salt rises to the surface through the action of evaporation. Salinization is reaching such a point that surface caking of salt was observed in a number of fields.

c) Slope

Slope may have considerable influence on soil salinization. Concave and moderate sloping lands are more prone to salinization than are flat and gently sloping lands. This occurs because irrigation water flow carries salt from higher areas and deposits it on concave and moderately sloping lands as well as in river bank (vazante)(Figure 14). The accumulation and rising of salt through the process of evaporation progressively salinizes these areas. Consequently, most irrigation is undertaken in level or nearly level alluvial lands.

Along the São Francisco River, the increase in soil salinity with the use of irrigation is basically the same for both flat and gently sloping lands used in the private sector (Table 31). Salinity increases from low levels to medium levels. For most public-sector land, salinity rises sharply, from low to high levels in flat fields and very high levels in moderately sloping fields. The exceptions to this are samples from a few gently sloping fields which register low levels of salinity. These come from a specific part of the Bebedouro project which is slightly higher than the rest of the fields in the project and so salt flows away from them.

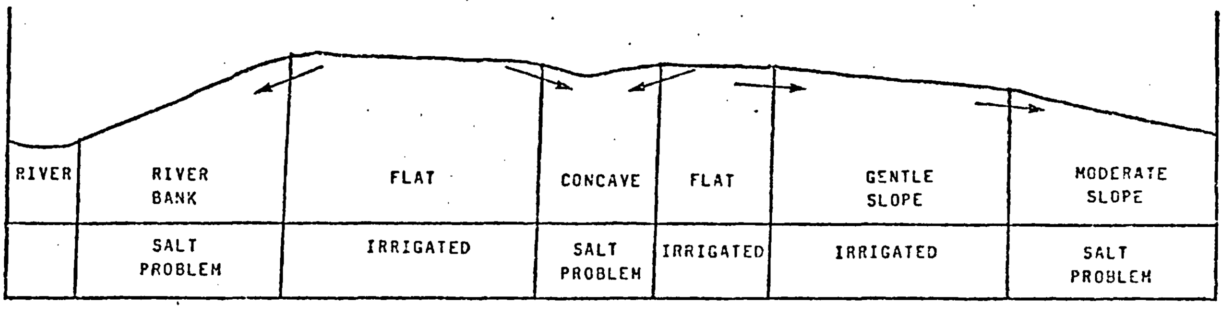


Figure 14. Schematic Topographical Perfile of an Irrigation Field and Movement of Salt (Arrows).

Table 31. Soil Salinity according to Slope on the São Francisco River.

Slope	Never Irrigated			Irrigated > 8 Years		
	No. Samples	Mean EC(a)	Level of Salinity	No. Samples	Mean EC(a)	Level of Salinity
PRIVATE SECTOR						
Concave	8	475	medium	0	-	-
Flat (0-2°)	40	225	low	52	488	medium
Gentle slope (3-5°)	4	275	low	4	476	medium
Moderate slope (6-10°)	0	-	-	0	-	-
PUBLIC SECTOR						
Concave	0	-	-	0	-	-
Flat (0-2°)	4	100	low	8	975	high
Gentle slope (3-5°)	8	124	low	4	280	low
Moderate slope (6-10°)	0	-	-	4	1810	very high

Source of Data: Field Research.

(a) Electric Conductivity of 1:1 soil extract (micro mhos/cm at 25°C).

The influence of slope in the process of salinization was found to be of secondary importance. Salinization was found to be just as serious on flat as on sloping land, hence, other factors, such as years irrigating, soil texture and the use of highly saline water, are of more importance (Table 32). The highest readings were obtained in the lands closest to the river. These lands are irrigated more often and they are also inundated more frequently by seasonal flooding.

Table 32. Soil Salinity according to Slope on the Tributaries.

Slope	Never Irrigated			Irrigated > 8 Years		
	No. Samples	Mean EC(a)	Level of Salinity	No. Samples	Mean EC(a)	Level of Salinity
PRIVATE SECTOR						
Concave	0	-	-	0	-	-
Flat (0-2°)	8	163	low	16	1571	very high
Slight slope (3-5°)	0	-	-	8	2323	very high
Moderate slope (6-10°)	0	-	-	0	-	-
PUBLIC SECTOR						
Concave	0	-	-	4	2630	very high
Flat (0-2°)	8	198	low	16	1047	high
Slight slope (3-5°)	4	341	medium	0	-	-
Moderate slope (6-10°)	0	-	-	0	-	-

Source of Data: Field Research.

(a) Electric Conductivity of 1:1 soil extract (micro mhos/cm at 25°C). Custódia readings included (except salinized field).

d) Irrigation Technology

When initial soil, terrain and water conditions do not pose serious problems for irrigation, as along the São Francisco River, soil salinity was found to be worse on farms where more capital-intensive forms of irrigation are used (Table 33). While the level of salinity remains low over time for samples taken from low intermediate technology farms along the São Francisco, it rises from a low initial reading of 222 micro mhos/cm to readings just into the high level of salinity for high intermediate technology farms. The highest readings for the private-sector were found on capital-intensive farms. The use of more capital-intensive types of irrigation in the private-sector is highly correlated to rising soil salinity, $r_{xy} = 0.81$. The highest readings of all irrigation along the São Francisco River were encountered on the CODEVASF Bebedouro project where capital-intensive methods are used and fallowing is not practised.

Table 33. Soil Salinity according to Technology Type along the São Francisco River(a).

Technology Type	Never Irrigated			Irrigated > 8 Years		
	No. Samples	Mean EC(a)	Level of Salinity	No. Samples	Mean EC(a)	Level of Salinity
PRIVATE SECTOR						
Labour-intensive	-	-	-	-	-	-
Low intermediate	20	224	low	24	277	low
High intermediate	24	222	low	20	614	high
Capital-intensive	-	-	-	12	668	high
PUBLIC SECTOR						
Capital-intensive	12	115	low	16	1009	high

Source of Data: Field Research.

(a) Excluding samples from concave areas.

(b) Electric conductivity of 1:1 soil extract (micro mhos/cm at 25°C).

Fallowing was observed to be important for reducing the risk of salinization and the absence of fallowing in the public sector and on many farms of the tributaries helps to explain why these registered higher salinity levels. Most private-sector farmers on the São Francisco River fallow fields for one to two years after having used them for one year. In addition, cattle are put to pasture in these areas which also aids in the recuperation of the fields. If this is not sufficient fallow time, fields whose productivity have seriously declined are fallowed for even longer periods.

Moreover, farmers of the private-sector also practise a form of crop rotation which they believe reduces the risk of salinization.

worsen natural tendencies toward salinization. The fertilizers and pesticides used all contain various kinds of salt which is incorporated into the soil during cultivation. When these are used in greater quantities, more salt goes into the soil. Furrow irrigation is the main irrigation method utilized on capital-intensive farms, and as more water is used, salinity increases faster with this method. Drainage systems, when they exist at all, are not properly maintained and this problem, combined with that of poor levelling of the land, means that all the disadvantages of capital-intensive irrigation are present but few of the advantages.

Indicative of this is the fact that in a few years of existence, 29% of the plots of the DNOCS Moxotó project already have grave problems of soil salinization or faulty infrastructural works. Similar problems were observed on the other CODEVASF and DNOCS projects of the study area. Moreover, DNOCS/Noronha (n.d.) report that 12% of the agency's irrigated area is being adversely affected by soil salinity and a further 7% has been abandoned altogether. So contrary to the belief of government technicians and extension agents that the use of more sophisticated irrigation systems in the Sertão can overcome the environmental limitations of the zone, their use merely worsens the situation in the long-run.

CROPPING AND SALINITY

Salinization is, therefore, a real problem for irrigation in places where soil and water conditions are favourable for its practice, such as along the São Francisco River, and even more so where conditions are less favourable, which is the case for most of the Sertão. This problem, in turn, restricts which traditional crops can be exploited and which new ones can be introducted.

As yet for most private-sector farmers of the São Francisco River salinization has not affected cropping in a very adverse way. Of the crops exploited only beans are a low tolerance crop whose productivity can be seriously diminished by medium levels of salinity (Table 35). Most other crops planted there fall in the medium tolerance group whose productivity is lowered by medium levels of soil salinity but not enough to discourage their cropping. The same cannot be affirmed for private-sector and public-sector irrigation using more capital-intensive methods because soil salinity is high and one would expect a process of falling returns to make irrigation unviable there in the near future.

Table 35. Salinity Tolerance of Irrigated Crops Appropriate for the Study Area(a).

Low	Medium	High
PRESENTLY IRRIGATED		
beans, limes, oranges	carrots, grapes, maize, melons, millet, onions, rice, tomatoes	cotton
POSSIBLE INTRODUCTIONS		
almonds, apricots, avocados, celery, green peas, plums, strawberries, various pastures	alfafa, brocoli, cabbage, castor oil, cucumbers, lettuce, olives, peas, potatoes, peppers, sunflowers, various pastures	asparagus, date palms, greens, spinach, sugar beets, various pastures

Source: After Withers & Vipond (1974).

(a) The authors list mainly temperate zone crops and pastures.

The impact of salinization on cropping of the tributaries is much more serious. The very high salinity rules out a number of traditional staples, such as beans, maize and rice, as well as newer irrigation cash crops, like onions, melons and tomatoes. However, in comparison to dry farming yields, farmers still find irrigation more advantageous to exploit even if yields of these crops are falling. In the long-term, though, the point could be reached where declining returns make irrigation uneconomic for most crops.

To overcome this problem one farmer was experimenting with irrigated short-cycle cotton which has a high tolerance to salinity. He was pleased with the results but the researcher observed stunted and discoloured cotton plants in his field. A number of farmers also plant algoroba trees (Prosopus jubiflora), capim de planta (Panicum purpurascens) and irrigated elephant grass for cattle fodder which appear to be highly tolerant of salt. Hall (1978) also reports the use of elephant grass on the DNOCS São Gonçalo project where it is planted in salinized areas. From this it seems that the best strategy for tributary farmers is to irrigate larger areas of salt resistant pasture and to crop smaller areas. Furthermore, given the characteristics of the soil and the poor quality of water, capital-intensive methods should be avoided in cropping. Also, the absence of or proper maintenance of drainage systems in clay soils, means that crop rotation and fallowing must be practised to prevent the build up of soil salinity.

As the situation on the tributaries is similar to that of most of the Sertão such a strategy is probably the best to pursue for irrigation throughout the zone. Even where environmental conditions are more favourable, as along the São Francisco River, the presence of medium and high levels of salinity means that care must be exercised to maintain fallowing, to avoid adopting those capital-intensive techniques which aggravate salinization, and to improve drainage methods.

7. THE CHOICE OF IRRIGATION TECHNOLOGY

In this chapter the question of who adopts which kind of irrigation technology is posed. To answer this, the analysis proceeds at the level of the farmer. The ability to utilize more capital-intensive forms of irrigation will be shown to be ultimately dependent on farm size and class position. Many of the other factors which, according to modernization theory, are thought to be decisive for the process of technical innovation will be shown to be of marginal importance in the study area. In fact, such factors as prior experience, access to credit, access to rural extension and technological information, level of education and age are demonstrated to be dependent on farm size and class position.

In the Sertão, more capital-intensive methods are most frequently utilized on larger farms owned by upper class individuals. By virtue of their social prominence and capital resources, large farmers obtain subsidized credit on a regular basis, have better access to rural extension services and farm information in general, have a higher education and are middle-age individuals who have been practising irrigation for a relatively long period.

In addition to these advantages, large farmers in many parts of the world also enjoy a privileged position in national development policy and they are often given preference for special loans and rural extension services. Röling _et al._ (1981) best summarize why governments tend to favour large property holders. Large farmers plant bigger areas so that the spatial effect per unit of effort is greater. These property holders are expected to form the future core of commercial farmers who will provide the nation with food and export earnings. They are eager for new information and follow advice, hence faster results are achieved. Large farm owners are powerful and, thus, can demand more attention, will complain and can even threaten bank managers and extension agents if they do not receive the services that they want. Large farmers have the economic means with which to try new ideas, while smallholders need credit which they rarely receive in developing countries. Large property owners speak the same language as government agents so that communication is easier between them. Finally, large farmers are an intellectual challenge whose keen questions keep an agent on his toes.

Whether farmers utilizing capital-intensive methods really attain higher levels of productivity and earn greater profits are questions which are treated in the next chapter. The main concern here is to prove that large property owners are able to utilize more expensive farming methods because they monopolize the productive resources and not because they are inherently more innovative by nature.

Whereas in private-sector irrigation, technology type varies greatly according to the different situation of each farmer, irrigation technology on the government projects is invariably capital intensive by design. As a consequence, project farmers are fitted to the technology and not vice versa. A conscious effort is made to control the economic and social traits of recruited farmers in such a way as to select what are considered to be the best farmers available. Regional planners usually hold the modernization view of development so the selection process for public-sector irrigation favours farmers who score highest in the various criteria usually thought to be important for rural innovation according to this theory. The success of the projects has thus become an end in itself, irrespective of local needs, and only a select minority of Sertanejo farmers benefit from the government programme.

PRIVATE-SECTOR IRRIGATION

Farm Size, Capital Resources and Class Position

As occurs elsewhere in the Northeast (Bicalho, 1980; Figueroa, 1977; Gross, 1970; MINTER, 1973) and indeed in most developing countries (Arnon, 1981; Griffin, 1981; Hunter, 1969; Pearse, 1980), upper class farmers are the ones who are in the best position to mobilize more resources and to receive new information that becomes available. As Pierson (1972) also noted, the first pioneers in irrigation along the São Francisco River were large ranchers and senior civil servants who had the means and the desire to fulfil new consumer needs by experimenting with an expensive new agricultural system. Today, these individuals are those who possess the longest experience with irrigation and due to their social prominence, they receive the lion's share of bank loans and technical assistance despite the fact that other farmers have greater need of these services. The children of upper class farmers also share these advantages.

This does not necessarily mean that wealthy farmers are inherently more 'open' to change than are poorer ones, but rather individuals of the upper class are in a position to take advantages of new opportunities. Moreover, official policy often institutionalizes this bias. Bank loans and rural extension services are channelled to large commercial farmers because these farmers are thought to be more receptive to change and this becomes a self-fulfiling prophesy.

Historically, ranch and herd size have defined class position in the Sertão. In the past, a wealthy man of the upper class owned dozens of ranches and his herd of cattle was numbered in thousands. Land and livestock made up nearly all of an individual's capital holdings. The introduction of irrigation has changed the land's capacity to create wealth and more investment capital is now needed in order to purchase the equipment necessary for tapping the land's potential. In sum, capitalized farming has replaced peasant farming.

This complicates the task of defining farm size. As Morgan and Munton (1971) and Symons (1972) show, mere size of holding is an inadequate measure of farm size. This is particularly true for irrigation in the Sertão, where the quality of land varies greatly from farm to farm. Some farms may consist of only 10 or 20 hectares of island alluvial land, all of which can be exploited with irrigation. On the other hand, a farm located on the mainland facing the São Francisco River or on the tributaries might possess hundreds of hectares of interfluvial land but only a mere 5 hectares may be alluvial land appropriate for irrigation. Furthermore, a farmer might own 50 hectares of good land but may only possesses the means to irrigate 2 hectares a year of such low cost crops as rice, beans or manioc. Another farmer might intensely exploit his 10 hectare total with a succession of harvests per year of cash crops utilizing expensive techniques.

Irrigation farm size is defined here by the amount of land that is irrigated during the course of an agricultural year (Table 36). As income on the irrigation farms along the São Francisco River is almost exclusively derived from irrigation and the interfluvial land, is hardly exploited at all, only the irrigated area is considered. This is less true on the tributaries, but irrigation still accounts for most of the income of these farmers.

The farm size intervals were set by matching local criteria for defining farm size to that of the amount of work involved with irrigation. A small farmer utilizes mainly his own family labour force and, occasionally, that of a limited number of sharecroppers, so he exploits less than 10 hectares. A medium farmer exploits from 10 to 29 hectares but only a small part directly and the rest is worked by from 10 to 20 sharecroppers. A large farmer employs from 20 to 50 sharecroppers to irrigate an area of between 30 and 79 hectares. A very large farmer employs more than 50 sharecroppers or wage labourers to work an area of more than 80 hectares.

Table 36. Distribution of Private-Sector Farms in the Study Area according to Annual Irrigated Area.

Farm Size	Annual Irrigated Area (Ha)	São Francisco River		Tributaries	
		n	%	n	%
Small	< 10	16	34.8	21	80.8
Medium	10 - 29	12	26.1	4	15.4
Large	30 - 79	12	26.1	1	3.6
Very Large	> 79	6	13.0	0	-
Total	-	46	100.0	26	100.0

Source of Data: Field Research.

A strong relationship was found to exist between farm size and technology type (Table 37). On the São Francisco River only small farmers practise labour-intensive irrigation and 60% of those that utilize a low intermediate technology are also small farmers. The majority of farmers who use high intermediate technology are large farmers. Exclusively large and very large farmers attain a capital-intensive level. This relationship is reflected in a high Pearson correlation coefficient value of $r_{xy} = 0.72$ for mainstream São Francisco farmers.

The situation on the tributaries is roughly the same and the correlation coefficient value is $r_{xy} = 0.49$. Labour-intensive and low intermediate technology are used principally on small farms, while high intermediate technology is utilized on medium and large farms. As yet, farms there do not reach a size that enables the use of capital-intensive technology.

Table 37. Technology Type according to Farm Size in Private-Sector Irrigation of the Study Area.

Technology Type	Farm Size				Total	
	Small	Medium	Large	Very Large		
	%	%	%	%	n	%
SÃO FRANCISCO RIVER						
Labour-intensive	100.0	0	0	0	2	100
Low intermediate	60.0	40.0	0	0	20	100
High intermediate	13.3	26.7	53.3	6.7	15	100
Capital-intensive	0	0	44.4	55.6	9	100
TRIBUTARIES						
Labour-intensive	90.0	10.0	0	0	10	100
Low intermediate	100.0	0	0	0	11	100
High intermediate	20.0	60.0	20.0	0	5	100
Capital-intensive	-	-	-	-	0	100

Source of Data: Field Research.

In addition, many farmers of the tributaries who adopt irrigation start with small areas of a cash crop, usually onions, which has diffused in a sophisticated technological package. The crop simply does not produce properly without the use of pesticides and fertilizers. Nevertheless, it must be noted that the capital equipment of these farmers is simple and that it is the necessity to use pesticides and fertilizers which most raise their overall technological level. This means that farmers planting modest areas of a hectare or two are almost forced to use a low intermediate technology from the start, which explains why many small farmers are found at this level.

Prior Irrigation Experience

At first glance it seems almost obvious that farmers with more experience with irrigation are those who practise more capital-intensive types. In the gradual change from peasant farmer to capitalized farmer and from subsistence to commercially orientated production, farmers of less developed countries slowly build up technical know-how, the capital necessary to finance the adoption of new farming methods and, finally, the courage to risk their scarce resources on the most promising of these (Hodder, 1975; Hunter, 1969; Symons, 1972).

Such change may be evolutionary but there is no reason why it must be unilinear and all stages be repeated. As Epstein (1971) shows for India, new crops can be introduced in association with new practices and stages can be skipped. This author found that this was easier to accomplish with new crops than trying to promote change in traditional crops because these already are associated with a tried and tested technology. While this was seen to be the case for irrigation in the Sertão, only a few stages were skipped and new methods can diffuse to traditional crops after having been proven with introduced crops. Moreover, this change did not involve an abrupt leap from a labour-intensive technology to a capital-intensive one, as happens to farmers who are selected for government irrigation projects.

Farmers on the São Francisco River do not usually start out by irrigating with an expensive technology. Instead they begin with a simpler type, which is within their means, and with which they will not initially risk too much of their modest capital resources. This can be seen in the relationship between years of experience and technology level. After a number of years they slowly start to use more sophisticated equipment and practices (Table 38).

No labour-intensive farmers were found to have long irrigation experience, while half of those at the low intermediate level have eleven or more years of experience. This increases to 92% and to 100% respectively for farmers utilizing high intermediate and capital-intensive technology.

Table 38. Technology Type according to Period of Irrigation for Private-Sector Farms of the Study Area.

Technology Type	Number of Years Irrigating 1-2	3-4	5-7	8-10	11 & More	Total n	Total %
	%	%	%	%	%	n	%
SÃO FRANCISCO RIVER							
Labour-intensive	50.0	50.0	0	0	0	2	100
Low intermediate	0	12.5	25.0	12.5	50.0	16	100
High intermediate	0	0	8.3	0	91.7	12	100
Capital-intensive	0	0	0	0	100.0	7	100
TRIBUTARIES							
Labour-intensive	14.2	0	28.6	28.6	28.6	7	100
Low intermediate	36.4	27.3	0	9.1	27.3	11	100
High intermediate	0	20.0	0	0	80.0	5	100
Capital-intensive	-	-	-	-	-	0	-

Source of Data: Field Research.

However, only a moderate Pearson correlation coefficient of $r_{xy} =$ 0.38 was found to exist between years of experience and technology level for farmers along the São Francisco River. The relationship was not higher because some of the farmers utilizing intermediate technology types have many years of experience but have not yet adopted a more capital-intensive type of irrigation. They either do not have the means to do so or do not think a more expensive system would be as profitable as the one they are presently using.

The findings are less conclusive on the tributaries and the correlation coefficient of is low, $r_{xy} = 0.11$. While 80% of the farmers with a high intermediate technology have long experience, the farmers practising the other two types have varying amount of experience.

Some experienced farmers on the tributaries still use a labour-intensive technology because of the nature of the crop exploited. Pasture and rice do not require more intensive inputs in order to produce a satisfactory yield and so farmers see little incentive in utilizing more expensive irrigation methods. Irrigation itself vastly raises the output of fodder by permitting a number of cuttings per year. The use of irrigation on the tributaries for rice cropping guarantees the harvest which is considered a good enough achievement for a crop that is grown mainly for subsistence.

The nature of the activity exploited also explains how stages in technical change are skipped for certain cash crops. This is particularly true on the tributaries where some farmers have just adopted irrigation, yet employ an intermediate technology and have not passed through a labour-intensive stage. As mentioned before, onions and other cash crops diffuse as relatively sophisticated packages. So the technological level of some farmers who may have been practising irrigation for only a short time can be fairly high. Even so, to attain higher levels of technology longer periods of experience are needed. Irrigation for most farmers on the tributaries is a fairly new activity and only 39% of them have been practising irrigation for more than ten years as compared to 70% along the São Francisco River, which is one reason why main stream farmers on average use more intensive irrigation methods.

Access to Credit

There is a common belief in Brazil, both within government and without, that credit is of great importance to enable farmers to adopt innovations (Goodman & Redclift, 1981). On the other hand, Hunter (1969) has observed that the need for official credit is often over generalized because many developing parts of the world have experienced surprising advancement of agricultural practices with small amounts of bank loans. This author feels that the income surplus of successful farming is the best source of capital and that official credit runs into less practical difficulties when it is given to farmers who are already on the way to intensive, commercial agriculture and who are at a point when they need to buy expensive capital equipment.

Having said this, it should be pointed out that there is a general tendency in developing countries for farm credit institutions to come under heavy political, economic and administrative pressure to lend the bulk of their funds to large land-owners. Loans to small farmers are more costly, difficult to administer and have high default rates (Arnon, 1981). Much the same occurs in the Northeast (Bicalho, 1980; Coelho, 1978; Figueroa, 1977; MINTER, 1973) and in the Sertão.

It will be argued here that while credit was important for aiding the adoption of irrigation in the pioneer years, credit has not been evenly distributed and so it does not play as constructive a role as it could. Moreover, contrary to what Goodman & Redclift (1981) hold, credit will be shown to have been unrelated to the adoption of new farming techniques by poor farmers. This type of farmer has had to rely on his own creative mix of production strategies in order to generate capital for intensifying farm methods.

In the early 1950s, when irrigation started to develop in the study area, a number of state and federal banks and agencies became involved in encouraging the expansion of the activity as well as in its technical improvement. The Banco do Nordeste do Brasil, the Banco do Brasil and the Banco do Estado de Pernambuco provided credit for local farmers to purchase, successively, waterwheels, deisel pumps and electric pumps, which were crucial for adopting irrigation. This was also done in association with SUVALE, the Ministry of Agriculture, the Pernambuco State Secretariat of Agriculture, local agricultural co-operatives and the Rural Electrification Co-operative during the 1950s and 1960s.

In addition to providing investment capital, the banks also loaned funds which enabled farmers to meet the operating costs involved in planting expensive irrigation crops. In the less monetarized local economy of the late 1940s and 1950s, the costs involved were considerable, even for large farmers. Hence, government aid for the São Francisco irrigation area was crucial for allowing a capital accummulation cycle to begin. This enabled irrigation to spread rapidly and its technology evolved relatively fast. Farmers increased their own stock of capital through high crop profitability and government loans helped them to raise the money necessary to plant on an ever larger scale.

Today, loans are frequently tied to technical assistance from local extension agents and a loan request must pass through their office before going on to the bank for approval. With the extension agent's approval a loan is almost guaranteed, but a farmer at times has to adopt certain technical recommendations which he might not otherwise do and that, from his viewpoint, can increase expenses unnecessarily. Farmers particularly resent this when methods that have not, as yet, been sufficiently tested must be adopted and when they are recommended by a young, inexperienced extension agent of urban origin. Nesbit (cited in Arnon, 1981) reports an identical situation for Colombia, which is one of a number reasons why many farmers there avoid credit institutions.

Irrigation planting loans are calculated to include the use of various types of pesticides, fertilizers and tractors and all labour is treated as waged. Some farmers might not use all the inputs and almost none use salaried labour for all cropping activities. The majority employ sharecroppers and some use mainly family labour. Sharecroppers receive a weekly cash advance but this is less than what they would receive if all members of the family working in the plot were waged. So, farmers receive more money in a loan than they actually use to pay for immediate production costs. For small farmers the extra money could help them to pay household expenses and to see them through to the harvest. With this they would avoid selling their crop at a cheap price before harvest or becoming indebted to a store owner. The extension agents calculate the loans with this purpose in mind and this is laudable, but the farmers who receive loans do not have these problems.

As funds for loans are limited and there are not enough to go round only a minority of farmers receive credit. Repayment is strictly enforced. Loans are secured by land and are made more often to farmers who appear best able to repay. Therefore, the combination of political pull, social status, bureaucratic procedure, loan security rules and even occasional outright preference for credit to large land-owners has always favoured large and medium farmers.

All large and very large farmers on the São Francisco River receive credit regularly. They also have major structural improvements financed by the government either directly through bank loans and special loans from SUDENE or indirectly through federal income tax incentives. In addition, all medium farmers have, at one time or another, taken out some kind of farm loan, though only 40% do so regularly.

In sharp contrast, only one smallholder interviewed had ever received a loan. It is true that many of the latter are not inclined to request planting loans on a regular basis for high risk cash crops because they do not wish to put their farm on the line at each harvest. However, most small farmers would like to at least take out an occasional long-term loan to buy an electric pump or some other important capital item that would enable them to adopt irrigation or to enlarge their cropping area. They rarely can do so just as Arnon (1981) and Hunter (1969) observe to be common in the rest of the developing world. Smallholders and tenant farmers run up against strong institutional barriers and government policy of the type which Crouch & Chamala (1981) term the progressive farmer model of diffusion coupled with trickle-down income policy.

Brazilian government and bank policy have long favoured the lending of public funds to larger farmers, who, in the view of extension agents and bank administrators, seem more inclined to adopt innovations and who are better credit risks. The structure of bureaucratic advancement in the banks quite often encourages managers to show positive results. If all loans are repaid on time and in full, then it reflects well on a manager's chances for promotion and this is best accomplished by lending to large farmers. Moreover, as Arnon (1981) and Hunter (1969) cite for other parts of the developing world, bureaucratic forms and procedures of exaggerated complexity pose a major obstacle for poorer, less literate farmers.

The degree of bias in credit to larger farmers was seen to vary through time and from place to place depending on changing government policy and on the particular attitude of the individual bank managers involved. For many years, there were only two agencies of the Banco do Brasil to serve the general vicinity of the study area. One is located in Cabrobó and the other in Juazeiro. The Juazeiro agency was important for the development of irrigation on that stretch of the river (Ferraz, 1975), while the Cabrobó agency served the main irrigation area further downstream. Interviewed farmers complain that the managers of the Cabrobó agency only give loans to the most important farmers and ranchers.

This situation prevailed until the mid-1970s when a new branch was opened off the main stream in Salgueiro. In 1978 another branch was opened in Belém do São Francisco and in 1979 yet another in Parnamirim. Farmers were quite surprised when the new agency in Belém opened and a young farm credit officer made a point of lending to smallholders. The manager of the new agency in Parnamirim also has a policy of lending to all comers.

A number of agencies of the state bank of Pernambuco were opened in important counties during the 1970s, including one in Belém. However, the state banks are often open to more political interference, which means that more prominent men receive loans and pressure can be brought to bear on farmers who do not toe the political line. No banks of any kind are located in the southern part of the study area, which restricts the development of irrigation there.

Medium and large farmers, therefore, receive most of the loans. Smallholders encounter numerous impediments even if they are willing to go to banks or if bank policy may, at times, officially favour them. It may now be asked whether this means that those who receive bank loans have a higher technological level because of this? On the face of it, this seems to be a foregone conclusion, and, indeed, the relationship between the two variables is quite high (Table 39).[1]

Both on the São Francisco River and on the tributaries, the proportion of farmers receiving long-term and short-term loans increases as one moves from less costly technology types to more-capital intensive ones. Also, the difference in credit made available to irrigation farmers along the São Francisco River as compared to that on the tributaries is striking. Only 8% of the tributary farmers have taken out bank loans at some time and even then not on a regular basis. More than half of the interviewed farmers on the São Francisco River take out loans every year while only 29% never have.

Table 39. Technology Type according to Frequency of Bank Loans in Private-Sector Irrigation of the Study Area.

Technology Type	Long-Term Capital Loans	Planting Loans			Total	
		Every Year	Occasionally	Never		
	%	%	%	%	n	%
SÃO FRANCISCO RIVER						
Labour-intensive	0	0	0	100.0	2	100
Low intermediate	20.0	13.3	26.7	60.0	15	100
High intermediate	73.3	66.7	26.7	6.6	15	100
Capital-intensive	100.0	100.0	0	0	9	100
TRIBUTARIES						
Labour-intensive	0	0	0	100.0	10	100
Low intermediate	0	0	0	100.0	10	100
High intermediate	50.0	0	50.0	50.0	4	100
Capital-intensive	-	-	-	-	0	-

Source of Data: Field Research.

Loans and technology level may be associated but what is basic to both is the size of the farm and the class position of the owner, which enable him to obtain loans in the first place. Those who receive the loans do, in fact, have a higher technology level but the relationship is such that the additional capital made available by loans is of marginal importance to intensifying farm methods.

Today, of those farmers who receive loans or tax credits, government subsidized funding is only important for the practise of capital-intensive irrigation. As most of these farms are not cost-effective, the use of capital-intensive technology would not be profitable without subsidy. However, the majority of these farm owners are wealthy outsiders who are more interested in speculative investment in land and in farm improvements which increase property value than in actually farming for profit.

Similarly, most of the other farmers who receive loans do not really need the money to finance their farm operations. The loans permit them to free capital, which would otherwise be tied up in production, for expanding the size of their farms as well as for investing in other non-farm activities. Loans would be important for smallholders utilizing an intermediate type of irrigation, in the way Hunter (1969) envisages, i.e. they are at the point where expensive equipment is needed. As their capital stocks are limited, loans could enable them to buy their own pump, or a better one, as well as to meet high operating costs. Instead loans go to large and medium farmers who already have passed this point.

Such a situation was not always the case and the loans made in the early years of irrigation on the São Francisco River, in fact, did enable local farmers to adopt the activity as the Banco do Nordeste (1957) observed at that time. Interestingly, the farmers of the tributaries are reaching a similar early stage in the adoption and expansion of irrigation. However, with the exception of one middle-sized irrigation farm in Parnamirim and a large farm in southern Chorrochó County, no other interviewed farmer of the tributaries has taken out a bank loan for irrigation.

As Hunter (1969) points out elsewhere in the developing world, successful farmers quickly become credit worthy, hence the São Francisco River farmers receive more credit. However, it could be that the farmers of the tributaries have not yet reached the point where they are sure enough of themselves and of the market conditions that they want to embark on irrigation as a larger enterprise. Significantly, the sole middle-sized irrigation farmer of Parnamirim started to adopt strategies involving greater risk after one particularly profitable harvest. With this money and with borrowed funds he planted larger areas and started investing in tractors for rental, which is particularly lucrative, and quickly entered into a cycle of capital accumulation.

The bank in Parnamirim is new and the manager is more disposed than most to pursue a more equitable loan policy, so perhaps local farmers will, upon reaching a threshold in their accumulation of capital, increasingly expand their area with the aid of bank loans. This seemed to have happened in the neighbouring counties of Terra Nova and Salgueiro where irrigation has been expanding rapidly with the aid of a favourable bank manager in Salgueiro. A number of loans have been made there for the construction of overflow dams along the Terra Nova River which permit the storage of water and enable more irrigation to be undertaken.

What needs to be done is to concentrate scarce capital on those farmers who have the least and in those areas where irrigation is starting to take hold. Richer areas, where more local capital has already been amassed, such as along the São Francisco River, should start receiving less subsidized bank loans and these funds should go to less wealthy medium and small farmers there. This requires some serious rethinking of the Brazilian development model and considerable institutional reform.

Rural Extension and Access to Information

Most government sponsored and informal agricultural information channels in developing countries suffer from the problems of too few personnel being spread over too large an area, of poorly developed communications infrastructure, of the general lack of funding and of personnel who are sometimes inadequately trained. All of these problems stem from the low priority given to agriculture in national development plans and this often causes governments to concentrate resources in areas and on farmers where the potential for change is greatest (Arnon, 1981; Hunter, 1969).

Such policy for the rural extension services, and particularly in reference to promoting the spread of Green Revolution methods in the developing countries, has come under intense criticism during the last decade. The progressive farmer model of diffusion together with trickle-down income policies have been held responsible for rising inequality in places where little had previously been present or for worsening it where it was found traditionally (Albrecht, 1982; Catelli, 1981; Crouch & Chamala, 1981; Garforth, 1982; McAllister, 1981; Röling et al., 1981; Roy; 1982).

Such occurs in the study area, but the role of the extension service by itself in both promoting rural change and rising inequality should not be exaggerated. As Crouch & Chamala (1981) and Hunter (1969) have observed elsewhere, simply improving the extension service by increasing the number of staff and redirecting its priorities overlooks the basic fact that a great deal of experimentation and communication concerning rural innovation occurs outside official channels for the dissemination of information.

Over the years farmers of the Sertão have received information concerning new irrigation methods from four sources: the government experimental farms, the rural extension service, the co-operative and other farms stores, and local innovators. The importance of each source of information for bringing about change has varied both temporally and spatially as have both the quality and quantity of information passed along each channel.

During the last fifty years, farm experimentation and rural extension in the Sertão have been undertaken by a number of different state and federal agencies. Funding for research and extension comes mainly from the federal government often with the support of international development agencies and banks. The approach that the various agencies have adopted in their efforts to promote rural innovation has varied through time according to changing policies at the federal and even at the international level.

a) Experimental Farms

In the study area, for over thirty years, the Pernambuco state agency Instituto de Pesquisas Agrícolas (formerly the Serviço de Fomento Agrícola) has maintained experimental farms in a number of localities. Along the São Francisco River there are stations in Petrolândia, Belém do São Francisco and Cabrobó and off the river in Parnamirim. Also in the late 1970s the federal government agency Empresa Brasileira de Pesquisa Agrícola (EMBRAPA) inaugurated a large experimental station at Petrolina.

In addition, one of the avowed objectives of establishing the various irrigation projects of DNOCS and CODEVASF that are distributed throughout the Sertão is to serve as examples of advanced technological methods for local farmers to follow. It is expected that local farmers will imitate the practices of their progressive colleagues on the projects and that rural extension agents will play an instrumental role in disseminating the latest ideas from the experimental farms and irrigation projects. In practice, a number of institutional barriers and constantly changing government policy prevent this from happening.

In the first years of irrigation along the São Francisco River, the experimental farms actually played a key role in promoting the diffusion of irrigation. On one island near Belém, during the 1940s, the Pernambuco state agency, the Serviço de Fomento Agrícola, installed a large pump to distribute water free to the farmers of the island. This set a highly visible example of a number of local farmers in one place using irrigation. However, by 1948, Carneiro (1952) saw that this service had already been discontinued and a conventional experimental farm had been established in its place. Over the years, the station has carried out experiments and has introduced a number of locally adapted seed varieties on the farms of influencial innovator farmers. This policy has proven to be relatively successful. Neighbouring farmers of all sizes have adopted much of what they saw the innovators using because many of the new methods are within their reach. This occurs because the station personnel work on specific problems which the farmers encounter.

This example notwithstanding, few of the state and federal experimental stations are still functioning in this manner. The state station in Cabrobó does not appear to be nearly as active as that of Belém and is more involved with mere experimentation than in trying to propagate the findings. Similarly, the large new EMBRAPA station established by the federal government in Petrolina seems to have little contact with local farmers and instead pursues more pure research. No farming activity at all was observed at the state station of Parnamirim which informants say has been the usual situation there for some time. Instead, the station serves merely as a source of phantom patronage jobs.

The change in policy from functioning experimental farms whose personnel used to try to actively promote the diffusion of their findings to that of closed research facilities or to that of their not functioning at all is lamented by the local population both on the São Francisco River and on the tributaries. This occurred not because farmers did not accept the innovations but rather because the government extension service was reorganized.

b) Farm Extension

During the 1950s and early 1960s conventional farm extension in the São Francisco Valley was undertaken by agents from SUVALE. In some other parts of the Sertão agents from DNOCS worked with farmers located nearby the experimental farms of the agency. In the 1960s the federal government set up a national rural extension service called the Associação Nacional de Crédito Agrícola Rural (ANCAR), later renamed the Empresa de Assistência Técnica Rural (EMATER), which took over this function from SUVALE and DNOCS.

EMATER has offices in a number of county seats of the Sertão and each office has between one and three agents. From their office the agents go out to visit some of the farms of a county in an effort to convince farmers to adopt innovations. One of the agents may be a vetinarian who is available for vaccinating and treating livestock.

In the study area, most counties along the São Francisco River have a local EMATER office. The agents of these offices have concentrated their efforts on irrigation farming along the main stream and have, for the most part, ignored dry farming. Very few counties off the São Francisco River have local offices and at the time of the research only larger towns and cities of there had one. Chorrochó County was under the jurisdiction of the Abaré office on the main stream and rarely did the local agent venture into the dry farming zone. The huge county of Parnamirim did not have an agent, nor was it served by the neighbouring Salgueiro or Ouricuri offices, 50 kilometres distance. Finally in 1980 a local office was opened.

Nevertheless, even in the irrigation counties, the local offices are chronically understaffed, usually having only one or two agents to cover counties whose size varies from 500 to 5000 km^2 and where secondary roads are poor. When agents can get away from the mountain of paper work at the office they are lucky if they visit thirty farms a month in counties where they number in the hundreds or even in the thousands.

Moreover, priorities for career advancement are such that work in the field is remunerated less than administrative posts and, over time, the system has become top heavy. As one moves to the regional, the state and, finally, the Northeast head office the number of agents in bureaucratic posts increases proportionately. A successful career is expected to lead to a high post in the state capital.

Agents are moved around a good deal with the aim of their gaining experience in different parts of ecologically and agriculturally diverse states. Hence, rarely do agents pass more than two years in any one place. Just when an agent is becoming familiar with local farming practices and has developed a rapport with the farmers of a county, he is transferred elsewhere. Thus, as one local innovator farmer put it, "These guys come to learn from us and not the other way around". When they do try to introduce a new practice, it may often not be suitable to local environmental and economic conditions or not have been tested enough with regard to the long-term effects.

The concentration of extension services in the São Francisco irrigation farming zone, i.e. in one of the most favourable parts of the study area, is part of a shift in overall development policy which took place in the late 1960s. National and regional planners grew impatient with what they considered the meagre amount of rural innovation that had taken place in the Northeast and policy shifted to one of promoting accelerated, unbalanced development. Not only were extension services concentrated where change was thought to be most promising but they were focussed on progressive farmers as well. This meant that during the late 1960s and most of the 1970s the government took the view that medium and large property holders were in the best position to modernize their farming methods. Up to 1979, rural extension agents could only work with farmers who own more than 50 hectares of land. Smallholders, who are those farmers with the least access to outside information, were denied extension service. This also put small farmers at an even greater disadvantage in obtaining credit, for bank loans have to pass through the extension offices first.

In 1979 the policy was reversed and extension agents have had to give preference to assisting small farmers. However, the national criterion of EMATER for defining a small farm is 50 hectares or less, irrespective of varying ecological conditions and farming system. This can be quite a sizeable irrigation farm so that many relatively large farmers can still be served. The effects of the new policy was implemented during the period of field research and was too recent for its impact to be felt in a significant way.

Extension agents are able to visit only a minority of farms, no matter what their size. Only a service where visits occur once every three months can be considered to be fairly adequate and just 26% of the interviewed farmers on the São Francisco River receive visits on such a regular basis (Table 40). A mere 7% of smallholders and surprisingly only 9% of medium size irrigation farms see an extension agent so frequently in stark contrast to a majority of large and very large farmers who do. A full 87% of smallholders and 91% of medium farmers receive extension visits only once a year or have never been visited at all.

Table 40. Frequency of Extension Service according to Farm Size in Private-Sector Irrigation on the São Francisco River.

Farm Size	Once a Month	Once in 3 Months	Once in 6 Months	Once a Year	Never Visited	Total	
	%	%	%	%	%	n	%
Small	0	6.7	6.7	6.7	79.9	15	100
Medium	9.1	0	0	27.3	63.6	11	100
Large	22.3	33.3	11.1	0	33.3	9	100
Very Large	0	100.0	0	0	0	3	100

Source of Data: Field Research.

There is indeed a tendency for the technology of those farmers visited by extension agents to be higher (Table 41). An adequate service is received by 33% of the farmers practising a high intermediate technology and by all of those utilizing a capital-intensive type. A moderate Pearson correlation coefficient value of $r_{xy} = 0.48$ was found to exist between the number of visits and technology level for farmers along the São Francisco River.

Table 41. Frequency of Extension Service according to Technology Type in Private-Sector Irrigation on the São Francisco River.

Technology Type	Once a Month	Once in 3 Months	Once in 6 Months	Once a Year	Never Visited	Total	
	%	%	%	%	%	n	%
Labour-intensive	0	0	0	50.0	50.0	2	100
Low intermediate	0	5.3	5.3	5.3	84.1	19	100
High intermediate	16.7	16.7	8.3	16.7	41.6	12	100
Capital-intensive	20.0	80.0	0	0	0	5	100

Source of Data: Field Research.

Most of the different reasons cited above by Röling et al. (1981) are responsible for this situation and, once again, other more important factors, such as farm size and access to credit, are the basic variables upon which technology and access to extension are dependent. Large farmers already have a superior technological level to start with and inexperienced extension agents may even go to these farms to learn what to tell other farmers. In this sense technology level can cause the number of visits and not vice versa. In fact, many of the farmers who practise the most capital-intensive techniques bypass the agents and go directly to technicians of the experimental stations for information when needed.

c) Farm Stores

A very important source of information concerning agricultural innovation is the co-operatives and farm stores which are found in most county seats along the São Francisco River. The co-operative of Belém was established in the late 1930s, a decade before the start of irrigation there. It does not buy produce but rather sells farm utensils and supplies. By making industrial agriculture inputs available locally, farmers have been able to experiment with the different products offered for sale. A number of the products serve the same purpose and so farmers actively experiment with cheaper brands to see whether they are as effective as those which they have been using to date. The farmers are not traditionalists nor brand loyalist and quickly switch products in their constant search to reduce high costs and increase productivity.

Today the co-operative of Belém is part of a state-wide system. The main office in Recife buys goods in volume and distributes them to the local stores. However, the stores are only found in more important cities and farmers from the small communities have to travel to stores located in such cities. This can limit the diffusion role of the co-operatives because most farmers only go to other cities on rare occasion, and when they enter a farm store there, it is merely to make a purchase. This contrasts sharply with the behaviour of local farmers who come to town every market day and socialize amoung friends in the store. While doing this, a good deal of information is traded.

d) Local Innovators

The fourth, and perhaps most important, source of information is that between farmers themselves. As the society being studied is rural, on all occasions when farmers meet they talk about the weather, the state of the crops, market conditions and most any other aspects of agriculture. Someone may comment that another farmer they know has used a certain relatively expensive fungicide that proved to be effective against a dangerous plague. A friend may point out that the product in question is fairly expensive and yet another person may respond that losing a harvest is worse and so maybe the extra expense is worthwhile.

As extension agents are few and ineffectual, many experimental farms function poorly, and government projects have closed in on themselves, the main source of information is exactly that gained from other farmers. Of 31 irrigation farmers interviewed along the São Francisco River, 97% stated that, in one manner or another, they learned how to irrigate by working as sharecroppers or by observing what a neighbour was doing and decided to give it a try themselves.

The farmers of the tributaries, in turn, look to those on the São Francisco River as a model. Kinship and friendship ties form an extensive web throughout the area so that most farmers know someone in the principal irrigation zone with whom they can raise queries or even visit their farm. The tributary farmers also exchange ideas among themselves concerning the relative merit or difficulty encountered practising irrigation in their particular environment. As distance from the São Francisco River increases, information from nearby farmers becomes more important. Farmers of Parnamirim have learned from farmers further down stream on the tributaries and not from the main stream. Some of the tributary farmers downstream, in turn, have learned directly from the farmers along the São Francisco River.

Innovators are proud of their accomplishments and do not mind showing their prospering crops to others for they gain status by doing so. The Sertão has traditionally been an agricultural frontier of relative opportunity. And, much as Gregory (1975) observed in a similar area of Belize, farmers do not have a mentality of the closed peasant society type where what is good in life is seen as being inherently limited in quantity. Also, most irrigation farmers no longer believe in the envy-inspired evil eye which could make them reluctant to let others admire their crops for fear of causing the plants to wilt. The recent social and economic experience of dry farming zones of the Sertão may be approaching a situation where resources are becoming scarce, as is happening in the populous zones of highland Latin America upon which Foster (1976, 1979) bases his 'limited good' theory, but irrigation areas of the Sertão are places of rapid growth where such a trend has been reversed.

A situation where farmers do most of the experimentation and passing on of information is probably for the better. The farmers are developing a technology from 'below' so to speak (cf. Stöhr, 1981). As Hunter (1969) has observed elsewhere for peasant farmers, irrigation farmers of the private sector actively test methods and calculate costs carefully. Hence, the irrigation system which they have devised is one that is well attuned to local conditions.

This does not mean that government rural extension services are dispensible. A well-trained extension service, serving all farmers, integrated fully with the local experimental farms, and with agents who are local fixtures instead of transient bureaucrats, could be of help to the farmers in their efforts to test new farming methods.

Level of Education

In rural development theory, education is frequently considered to be vital for promoting technical progress. In the early literature, biased characterizations of ignorant and uncultured peasants, who lack schooling, went hand-in-hand with this belief and the factor of low levels of formal education was assumed to pose a seriously barrier to rural innovation. An example of this for the study area is Duque (1980, originally 1949). Such views are rarer today in the international literature but regional planners of the Northeast still hold these preconceptions, e.g. SUDENE (1973, 1974, 1979). Katzman (1984) has also noted this view in the planning literature of the Northeast; he suggests that 'peasant ignorance' is often cited as a principal cause of the region's continued underdevelopment, despite the enlightened efforts of development agencies.

The value of schooling is especially seen to be exaggerated when one examines the content of what is being taught. Recently, Arnon (1981), Hardiman & Midgley (1982) and Haswell (1973) have observed elsewhere in the developing world, that the curricula of the secondary schools, and even of the universities, are often irrelevant to the needs of transforming a rural society.

As in these other cases, the educational system of the Northeast is geared to a minority of students who will proceed on to higher education and ultimately, to urban professions. While some agricultural secondary school courses have begun to be taught in recent years, the emphasis of curricula, and more importantly, the promise of earning a high income and gaining status do not lie in farm studies.

With the right degree, usually in a liberal profession, obtained in the high schools and universities of the large cities, a young person gets a good job in the civil service. Increasingly, such an individual will also dabble in irrigation or it may even be his principal source of income, but few such part-time farmers would have learned anything in school which is of practical use on the farm. Students do learn 'culture' in school which is a whole mode of talking and behaving that enables them to communicate better with rural extension agents and, most importantly, with bank managers. However, this in itself is not a justification for the type of schooling received. Indeed, the onus of communication should not fall on the farmers but rather on those dealing with them, and it is far cheaper to train civil service personnel how to communicate with farmers than the opposite.

What can be said to be of practical value in schooling for promoting rural transformation is the progress and development ideology that is instilled. The schooling is certainly important in this respect, although the general changes occuring in Sertanejo society and the government propaganda on the radio and television are probably more important sources of this way of thinking.

Furthermore, there is no reason why radio and television for illiterates cannot be as effective as, or even more so than, formal education as a way of disseminating technical information. This is particularly true in less developed countries where newspapers and journals are a rarity in the interior. This is not to say that reading, writing and mathematical skills are not important for staying informed about innovations, prices and events on the national scene, but many farmers with only a primary school education can do this quite well.

Nevertheless, at first glance, it would seem that there is a relationship between educational attainment and level of technology (Table 42). Most farmers along the São Francisco River who use less costly irrigation methods did not finish primary school. High intermediate irrigation is usually practised by farmers who have frequented school up to four years, i.e. the primary level. Capital-intensive irrigation is found on farms whose owners have finished secondary school or have a university degree. The Pearson correlation coefficient for São Francisco farmers is high, $r_{xy} = 0.75$.

Table 42. Technology Type according to Educational Attainment for Private-Sector Farmers of the Study Area.

Technology Type	Illiterate or Sign Name	Primary School Incomplete	Primary School	Secondary School	University	Total	
	%	%	%	%	%	n	%
SÃO FRANCISCO RIVER							
Labour-intensive	100.0	0	0	0	0	2	100
Low intermediate	42.1	36.8	21.1	0	0	19	100
High intermediate	0	21.4	35.7	14.3	28.6	14	100
Capital-intensive	0	0	0	17.4	28.6	7	100
TRIBUTARIES							
Labour-intensive	22.2	44.5	22.2	0	11.1	9	100.0
Low intermediate	0	63.6	27.3	9.1	0	11	100.0
High intermediate	16.7	33.3	33.3	16.7	0	6	100.0
Capital-intensive	-	-	-	-	-	0	-

Source of Data: Field Research.

However, something is terribly amiss in this correlation, which might explain why education has been thought to be so important for so long. First, the data from the tributaries is not as conclusive as that from the main stream and a low correlation coefficient of $r_{xy} = -0.04$ reflects this. Second, and most importantly, on the São Francisco River, educational attainment is associated with technology level because class standing presupposes the two. The children of large farmers have the means of studying at school longer and to attending the quality institutions of the state capital, but, agronomy degree courses apart, the schools and universities there assuredly do not teach anything that has to do with farming.

Moreover, the scatter diagram of the correlation between education and technology for main stream farmers indicates the influence of a third variable. If the effect of class, as measured by farm size, is removed with a partial correlation which holds class (variable z) constant, the final value for the two original variables is seen to be lower, $r_{xy.z} = 0.43$.

The direct link between education and technology is seen to be weaker still if the operation of capital-intensive farms is examined. Individuals with university degrees are not farmers at all and many are outsider absentee landlords. Their level of schooling has no bearing on agricultural activities but rather on their other main occupation. Indeed, most farming decisions are made by semi-literate administrators. Level of education and social standing of the owner are really only important for obtaining the subsidized credit which makes the use of capital-intensive techniques possible. In sum, in order to practise an intermediate irrigation technology, which is the most appropriate for the present socio-economic circumstances of the Sertão and which is relatively sophisticated, a primary school education is more than adequate.

Age

Age is another variable which is thought to influence the adoption of new methods by farmers. When elderly people possess the economic power in a society, their conservatism is thought to be a barrier to progress (Dumont, cited in Arnon, 1981; Foster, 1973). As Chayanov (cited in Djurfeldt, 1982 and in Sahlins, 1972) has shown for peasant societies, older people are often those who, by being at the end of the life cycle, end up controlling the economic resources. In fact, in most societies, be it peasant or an industrial, older persons are the ones who have accumulated the most experience, property, capital or bureaucratic seniority, so if old age causes conservatism this would prevent change everywhere.

In the Sertão, the age of the farmer was only found to be relevant for explaining who adopts irrigation and not for determining who practises which type of irrigation (Table 43). If the two labour-intensive cases are excluded because of the small sample size, there is only a slight tendency for older persons on the São Francisco River to practise a more costly technology type. This argues against the idea of elderly conservatism and, in fact, some older persons have the means and pull to be able to utilize more expensive forms of irrigation. The more common age both on the São Francisco River and on the tributaries is the 41-50 group, but even they do not form a clear-cut majority. Very low Pearson correlation coefficient values of $r_{xy} = -0.07$ and $r_{xy} = -0.02$ were found to exist between age and technology for farmers along the São Francisco River and on the tributaries respectively. The scatter diagram for the two variable is of the random type and not of the linear or circumlinear type, which confirms the fact that the variable are unrelated.

More middle-aged farmers are found practising irrigation farming than dry farming (Figure 14). In rain-fed agriculture 73% of the farmers are over 50 years of age. However, this occurs not so much because younger farmers have a keener sense of innovation but rather due to the need for these individuals, when confronted with the problem of declining farm size in dry farming, to find resources and livelihoods elsewhere. The relatively small number of irrigation farmers over 50 years of age, as compared to those in the same group in dry farming, is instructive. Individuals of this age group came of age previous to 1950, before irrigation became important, and many of them had to emigrate. Those who came of age after 1950, i.e. who are 50 years of age or younger, are local farmers who chose to stay or are people from the dry farming zone who were attracted to the irrigation area.

Table 43. Technology Type According to Age of Private-Sector Farmer in the Study Area.

Technology Type	Age Group 31-40	41-50	51-60	61 & Over	Total	
	%	%	%	%	n	%
SÃO FRANCISCO RIVER						
Labour-intensive	0	0	0	100.0	2	100
Low intermediate	30.0	20.0	25.0	25.0	20	100
High intermediate	35.7	28.6	28.6	7.1	14	100
Capital-intensive	10.0	60.0	30.0	0	10	100
TRIBUTARIES						
Labour-intensive	11.1	33.3	44.5	11.1	9	100
Low intermediate	0	72.7	9.1	18.2	11	100
High intermediate	16.7	66.6	0	16.7	6	100
Capital-intensive	-	-	-	-	0	-

Source of Data: Field Research.

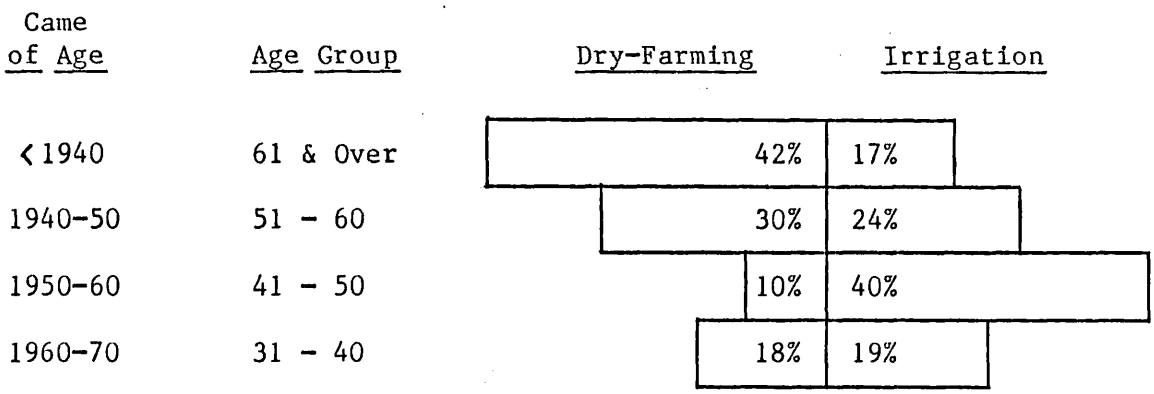


Figure 15. Distribution of Farmers per Age Group in Dry Farming and in Private-Sector Irrigation on the São Francisco River.

PUBLIC SECTOR IRRIGATION

It is common for the governments of developing countries to grow impatient with the apparently slow performance and meagre results obtained in promoting rural innovation. They are thus tempted to avoid the hard job of reforming the services of the Agricultural Ministries and instead set up special development corporations or involve other ministries in the effort. This further demoralizes the extension service and causes confusion of conflicting and overlapping functions (Hunter, 1969).

Public irrigation of the Sertão fits just such a situation. It is undertaken by the special agencies DNOCS and CODEVASF which are semi-autonomous bureaucratic fiefdoms of the Ministry of the Interior instead of the Ministry of Agriculture as are most farm programmes. The policy of the agencies since the late 1960s has been to intervene directly into the Sertanejo agrarian system, to thrust aside the prior 'archaic' technology and socio-economic structure, and in its place implant a capital-intensive irrigation technology and 'modern' socio-economic structure of commercial farming. Capital-intensive technology is, therefore, the starting point and the environmental and socio-economic conditions are made to conform to its requirements.

Family Project Farmers

During the first decade of the modern public projects, farmers were selected according to rigorous standards designed to assure the success of the expensive undertaking. The candidate had to have a long tradition in farming and preferrably they should be landless peasants and smallholders of the area which was expropiated. Recruits had to know how to read, write and make arithmetic calculations, which in the case of CODEVASF was particularly important as they had to pass a difficult entrance examination. The candidates had to be old enough to have a sizeable family yet young enough to be able to work hard. Moreover, they had to be healthy. Access to technical information, bank credit and capital, while important for evaluating their capabilities as farmers, would be taken care of by the project once selected.

Both for CODEVASF and DNOCS, the selection of project farmers today is still a long and complicated process. First, the agencies advertise, on the radio or by loud speaker on market day, that places are available on a particular project. Then, candidates fill out application forms and, in the case of DNOCS, wait for agronomists and social workers to come to interview them in their homes and in their fields. Besides direct questioning, the interviewer observes the cleaniness of the house, the state of the fields and asks neighbours if the candidate's family are orderly. Both agencies also, solicit information concerning police record and credit worthiness at the local bank and co-operative. Finally, both subject potential farmers to rigorous medical examinations.

All this information is then evaluated, assigned points and summed up in such a way that certain aspects are given more weight than others. DNOCS, for example, gives more weight to the size of the family work force, familarity with advanced cropping methods, type of access to land and a good bank record (Table 44). CODEVASF has a similar even more complicated system in which the age of the candidate and the size and sexual composition of his family as well as experience as an independent farmer are given most importance (CODEVASF, n.d. 3). In addition, formal classes are administered for three months in which the candidate's performance is evaluated before he is finally selected.

The whole process is done in such a way as to pick what are considered to be the best candidates, but this tends to favour property owners over landless peasants. In the case of the DNOCS selection process, property holders would be in a better position to be familiar with more advanced farming methods, have direct access to land, be more credit worthy, study more, be geographically stable, be less likely to have a criminal record, market produce more directly, own more livestock, possess more farm utensils and be familiar with advanced stock-raising methods. Many of the CODEVASF criteria for selection also favour land-owners.

Table 44. Indicators for the Selection of DNOCS Project Farmers

Indicator	Weight
Size of family work force	10
Familiarity with and use of advanced cropping methods	10
Type of access to land	8
Bank credit rating	7
Police record	3
Level of education	2
Geographic stability	2
General credit record	2
Form of marketing produce	2
Ownership of livestock	2
Ownership of farming utensils	2
Familiarity with and use of advanced stock-raising methods	2

Source of Data: Questionário de Seleção de Irrigante (DNOCS).

On the other hand, the social structure of the projects is not attractive to most self-respecting Sertanejo farmers so that the candidates who apply are not exactly those whom the agencies would prefer. Despite the bias to land-owners, most selected farmers are landless peasants who do not possess the socio-economic traits which planners consider important for the practise of sophisticated irrigation (Table 45). With a few exceptions, the farm owners recruited were minifundia holders who are not far removed from being landless peasants and who display a similar social background to that of the latter. Most of the non-farm workers selected were at one time poor farmers and for many their previous job had been working on the projects in the construction phase.

That the project farmers selected are landless peasants and minifundia landholders is commendable. One of the stated objectives for the projects is to provide work for poor Sertanejos who are most adversely affected by drought and who are most prone to emigrate. Of these, former owners of the land expropriated for the project and their workers are supposed to be given priority for selection. However, only a minority of the former owners and workers actually end up on the projects. The project technicians hold the view that they did not enter the project because they did not qualify in the selection process or that they simply did not wish to apply.

Table 45. Previous Occupation of Project Farmers of the Study Area.

Projects	Day-Labourer	Sharecropper and Others	Farm Owner	Non-Farm Worker	Total	
	%	%	%	%	n	%
DNOCS						
Boa Vista	0	58.3	25.0	16.7	24	100
Custódia	23.1	38.5	30.8	7.6	39	100
Moxotó	37.0	35.8	25.0	2.2	92	100
CODEVASF						
Bebedouro	33.8	13.9	18.5	33.8	65	100
PROJECTS RESEARCHED	29.5	32.3	24.1	14.1	220	100

Source of Data: Field Research.

The two reasons are related. The few former land-owners who were located for interviewing, stated that they did not want to subjugate themselves to what they consider to be a relationship of inferiority and dependency of project farmers to the administrative personnel. In the words of one project farmer, "Only those who are worst off make a try of it here. They have nothing to lose".

Besides the problem with the complicated selection process and farmer independence, the simple fact that projects can take from five to ten years to start functioning excludes many expropriated farmers. They lose their farm and have to move elsewhere in search of another or a job. Hence, in the researched projects only four of the farmers of Custódia were from there originally, one from Boa Vista and two from Bebedouro.

On the other hand, it is convenient for the project administration if the selected farmers were previously landless peasants because they have always been in a subordinate, dependent situation and so can be more easily manipulated. In the words of one project administrator, "They follow orders better because of their humble background". Also, they have little choice because many were desperately looking for work. Even if their new situation is not that of a completely independent farmer, it is still better than if they were mere day-labourers or unemployed.

a) Prior Experience

The requirement of prior experience in farming, of course, makes good sense and all the project farmers at least grew up in the countryside. However, wanting candidates who are familiar with or who have used a number of capital-intensive farming methods is unrealistic. Even most medium and large land-owners who practise dry farming are unfamiliar with these methods. Only someone who has worked in irrigation would know of such advanced methods, but irrigation is not so widespread that most Sertanejo farmers will have had prior experience in it. Only one project farmer of the three family-farm projects studied in detail was found to have passed directly from being a sharecropper in private-sector irrigation to being a farmer on a project. In practice, the projects have to accept what is available, to the irritation of the administrative personnel. One project director commented to the researcher, "These hicks come down off a mountain and don't know anything".

b) Level of Education

Similarly, the education requirements are not in keeping with levels attained by most Sertanejos and particularly by those attracted to the projects (Table 46). The vast majority of farmers on all projects are virtually illiterate or have not finished primary school. Individuals of their social class did not have the opportunity to study either because schools were too distant from where they grew up or because they were needed in the fields. As discussed previously, this is not such a problem because the importance of education in promoting rural innovation has been overestimated. However, project administrative personnel hold the usual urban-bias belief and when problems of low productivity are encountered the low cultural level of farmers is often automatically blamed instead of project design.

Indeed, the projects demonstrate how farmers with very low educational attainments can practise quite sophisticated irrigation methods. No doubt they are given extensive technical assistance but if an improved extension service were provided for the private sector similar results could be obtained. As things are, an excessive number of extension agents have been concentrated on the projects, where the ratio of farmers per agent on DNOCS projects is six to one.

Table 46. Educational Attainment of Project Farmers of the Study Area.

Projects	Illiterate or Sign Name	Primary School Incomplete	Primary School	Secondary School	University	Total	
	%	%	%	%	%	n	%
DNOCS							
Boa Vista	32.0	56.0	12.0	0	0	25	100
Custódia	51.2	48.8	0	0	0	43	100
Moxotó	51.5	33.6	14.0	0.9	0	107	100
CODEVASF							
Bebedouro	10.1	59.6	28.3	2.0	0	99	100
PROJECTS RESEARCHED	34.7	47.4	16.8	1.1	0	274	100

Source of Data: Field Research.

c) Age and Family Size

Another pre-requisite of project candidates is that they be of 18 to 60 years of age, but preferably they should be 21 to 40 years of age on DNOCS projects and 33 to 48 years old on CODEVASF projects. At this age they can already have large families and still be in their physical prime. Reproduction rates are such that a 30 year old man can have a family of five children or more, the oldest of which can already be of an age that he can help in the fields. For both agencies a large number of children is desirable so that project farmers can have a large family work force at their disposal. CODEVASF, for example, has a system of selection which gives more weight to families with numerous adolescent boys.

With respect to family labour, this requirement did not work out as planned. As project farmers earn an income which vastly raises their standard of living, they too take on higher aspirations for their children's education. To continue studies beyond primary level, the children must either go and live in a county seat or spend nearly the whole day away from the farms. Consequentely, labourers from outside the project must be contracted to take their place.

With respect to the age group desired, young farmers are indeed chosen (Table 47). Whereas in the private sector a man of less than 30 years of age rarely has a farm, 20% of the project farmers fall in this group. Most project farmers are between 31 and 40 years of age as occurs in private-sector irrigation but comparatively few middle-aged and elderly farmers are found on the projects. As most land-owners of the Sertão are of these older age groups, quite possibly many of the expropriated farmers did not enter the projects for this reason. Hence, by ignoring the demographic patterns of the Sertão, the projects threaten the family structure and the well-being of the elderly of the region.

Table 47. Age of Farmers upon Entering Projects of the Study Area.

Project	Age Group 21-30	31-40	41-50	51-60	Total	
	%	%	%	%	n	%
DNOCS						
Boa Vista	20.0	44.0	32.0	4.0	25	100
Custódia	23.1	38.5	30.8	7.6	30	100
Moxotó	12.0	36.2	32.4	19.4	108	100
CODEVASF						
Bebedouro	26.7	48.6	17.8	6.9	101	100
PROJECTS RESEACHED	19.8	41.8	26.7	11.7	273	100

Source of Data: Field Research.

d) Health

A final criterion for selection that runs counter to local conditions, is good health. Individuals suffering from certain prevalent serious diseases, such as Chagas' disease and tuberculosis, are rejected. They are viewed as not having enough energy to do the hard work involved in irrigation. In addition, farmers and their family members who suffer from such curable diseases as measles, meningitis, tetanus, typhoid or whooping cough are discriminated against in the selection. These health pre-requisites eliminate many prospective candidates, and on the Bebedouro project, for example, Ferraz (1975) reports that 41% of the applicants were rejected for this reason alone. Again, it is the poor who suffer most from these maladies, due to their previous living conditions and nutritional standards. Ironically, the Custódia project is located in a focus area of Chagas' disease and healthy individuals are being subjected to the risk of contacting the disease.

In more recent years many of the criteria for selection have been relaxed when replacing project farmers who leave. In this situation, prior experience on a project and good health are paramount for being chosen. From the viewpoint of the project manager, this type of farmer has extensive experience in the practice of public-sector irrigation and he needs little further training. However, the new farmer is picked on a more subjective basis, which almost exclusively depends on what project personnel think of his capacity for work and his attitude toward the project. This system encourages favouritism of the kin of project farmers. For outsiders it creates a form of apprenticeship in which they may pass years working for a project farmer before an opening becomes available. First an outsider works as a seasonally-employed day-labourer until a place as a permanent worker for a project farmer becomes available. Only after some time in this position, might he be one of the chosen few who finally become a project farmer.

This kind of arrangement has always been the case on the Bebedouro project, where many former workers for the SUDENE experimental farm were among the first farmers to be selected. Today, they still make up 52% of the project farmers. Also some successful candidates for new projects have a similar background. On the oldest and smallest DNOCS project in the study area, Boa Vista, no project farmers had worked for DNOCS before but on the newer Custódia project 18% of the farmers have such a background.

Large Project Farmers

At the time of the field research, the DNOCS private-sector joint venture scheme was still on the drawing boards but CODEVASF had already chosen a number of large farmers for its rental scheme. Interestingly, the criteria used by CODEVASF for selecting these farmers is much simpler and less rigorous than that used for family farmers. A candidate only has to make a written request stating how much land he would like to rent, list his prior farming experience and technical knowledge, provide proof of his credit rating and a copy of his identification card. Apparently the 'high culture' of these <u>empresários</u> is evidence enough of their other capabilities.

CODEVASF is of the opinion that this rental scheme will result in the rapid introduction of a capital-intensive irrigation system similar to the one which CODEVASF uses. These 'businessman' farmers are expected to do this because, in the words of one high CODEVASF official, "They are more knowledgeable, will bring in and employ agronomists and technicians, will create jobs for waged labourers and always want to introduce and use modern farming methods". The few who have actually started to work their land have not done this. They behave exactly as normal private-sector farmers do. The technology utilized is a high intermediate type at best and, after having tried salaried workers, they quickly switched to employing sharecroppers.

Also it is extremely questionable about who is being given these rental contracts. One of the two farmers who were actually working the land at the time of the research is a foreigner. He was a former plantation owner in Africa. Another selected farmer, who was about to begin planting, is an American. A number of others selected are descendants from a Japanese immigrant agricultural colony located in a humid part of Bahia. Finally, two-thirds of the candidates picked are senior civil servants, civil engineers and wealthy merchants. Of the candidates an incredible 47% have no previous first-hand experience in farming and many are outsiders who were selected for their 'proven administrative skills'. These and most of the local wealthy merchants are merely speculators who have connections to local and regional personnel of the public irrigation agencies. They saw a chance to make a killing because after five years they have the option of buying an irrigation farm at a bargain price. However, many have made little or no progress in using the land and the researcher was informed that they would probably be cut from the programme.

Whether this happens or not, is besides the point, because almost all of the candidates had no business being chosen in the first place. With the exception of the merchants who share the same social circle as the project personnel, no local people were informed of the new rental system and hence did not apply. Local farmers had only heard of positions for waged labourers being advertised over the radio. It seems CODEVASF is so obsessed with showing positive results that the agency is losing sight of the fact that it was set up to promote the better well-being of the local population and not the enrichment of outsiders.

CODEVASF is increasingly turning to such outsiders and even has a number of new projects planned that set aside one-third or more of the area of the projects for large canneries. The Mandacaru sugarcane mill, owned by a coastal consortium, is already in operation on the Tourão project. In addition, the Maniçoba, Curaçá, Massangano and Salitre projects will all have large areas for corporation. The excuse for this as one official put it is, "These companies will also install processing factories, in general accelerate the expansion of irrigation, cost CODEVASF less and need less technical assistance". This is a classic statement of the much condemned progressive farmer mode of diffusion and trickle-down income policies. These actually end up costing the government more because the greater majority of the capital for these schemes comes from subsidized loans and tax credits. It seems that progress at any expense and trying to justify and maintain the existence of public irrigation will marginalize Sertanejo farmers. For the vast majority their role seems destined to be cheap day-labourers if the agencies get their way.

A number of unrealistic and discriminatory demands have, therefore, been made of Sertanejo farmers in the name of the success of the projects. Under the influence of modernization theory and due to the urban-bias of the planners, the pre-requisites for selection of farmers fly in the face of the social reality of the Semi-Arid Zone. The levels of education, age, family size and health needed to enter a family farm project work to the disadvantage of the former occupants of the land expropriated for projects. As a result, few local people actually benefit from the public-sector irrigation programme and the new rental scheme being introduced only makes matters worse.

More local people benefit from private-sector irrigation because it is a system which has developed from below. On the other hand, government efforts to fuel the process of technical change in the private sector by providing credit and extension services usually worsen inequities present in the system. Once again, many of these distortions arise because of the development model pursued by national and regional planners. Thus, if private-sector and public-sector irrigation are to develop in a way that is in accordance with the social reality of the Sertão overall government policy must be changed.

8. THE ECONOMICS OF IRRIGATION AND SOCIAL CHANGE

The aim here is to analyse the overall economic viability of the different irrigation systems of the Sertão. This involves not only examining the immediate costs and benefits but also focussing on the long-term consequences of the development of each system. A wide range of economic and social factors will thus be considered in relation the adoption and use of specific kinds of irrigation. These include questiòns of productivity & environmental risk; commercial orientation & market risk; costs, profits & farmer income; trends in farm size; employment opportunity; labour relations & worker income; standard of living; social mobility and patterns of migration.

Two types of comparison are made in respect of these topics. One concerns the comparison of irrigation with dry farming and the other involves the contrasting of private-sector irrigation with public-sector irrigation. In the comparison of dry farming with irrigation, many of the topics concerning dry farming have already been treated in Chapter 4, so the focus here is on irrigation and only general reference is made to dry farming. The main objective is to determine whether irrigation is capable of breaking the vicious circle of drought, low rural income, declining farm size, lack of jobs and emigration that prevail throughout most of the Sertão. Running parallel to this comparison is another in which private-sector and public-sector irrigation are contrasted with respect to which better resolves these problems.

Irrigation in general will be shown to enable farmers to plant larger areas, produce more and lose fewer harvests than is the case in dry farming. Moreover, farmers who use irrigation are able to exploit new lucrative cash crops as well as produce staples for the local market. Indeed, farmers first adopted irrigation in order to take advantage of new market opportunities and so increase their income. Substantially higher incomes allowed farmers to accumulate capital and to raise their standard of living. Rapid intensification in land use has thus overcome the problem of declining income, and more employment is now available for both farmer family members and for workers. As a consequence, instead of the typical situation of rural exodus prevailing, as in the rest of the Sertão, irrigation zones experience rapid demographic growth. Local people do not migrate and numerous outsiders are drawn in. Irrigation thus reverses Boserup's (1965) main proposition, i.e. population pressure leads to agricultural intensification.

In the comparison of irrigation types, private-sector irrigation is shown to better develop the potential which irrigation has for bringing about positive rural transformation. This occurs mainly because less costly production schemes are used in the private sector and the system as a whole is more attuned to the economic realities of Sertanejo farming. Private-sector farmers earn high incomes and re-invest profits into further intensifying irrigation more often than do public-sector farmers. Public-sector farmers only earn a relatively high income through government subsidy and the whole structure of the projects encourages them to invest whatever they can off their plot. Despite the occurrence of some land concentration, greater upward social mobility also is possible in the private sector. A sharecropping labour relations system permits workers to earn relatively high incomes and allows them to accumulate capital. The salaried labour system used in the public sector, on the other hand, permits little upward mobility. All these characteristics mean that private-sector irrigation stems the tide of emigration which the public sector does not.

FARM PRODUCTION, COSTS AND INCOME

The trends of area planted and production in irrigation during the period studied are the exact opposite to those of dry farming. Crop failure is rare and multiple harvests are made possible, something which is unheard of in dry farming. Irrigation farmers plant larger areas and produce more, which causes them to be more market-orientated than are dry farming land-owners. Net farm income is higher but so are costs of production and, consequently, market risk.

Few private-sector farmers use expensive irrigation technologies. This allows them to reduce market risk and to make more income per hectare than do public-sector farmers. At the same time, productivity is basically the same in both sectors. This is explained by the fact that most capital-intensive methods increase the productivity of labour rather than of land.

Private-Sector Irrigation

a) Production, Productivity and Environmental Risk

On the private-sector farms of the study area a steady expansion in irrigation cropping has been made possible both by its diffusion to a larger number of farmers and by such technological change as improved devices for lifting greater amounts of water and the wider use of pesticides and fertilizers, which further assured harvest success. The area planted and the production of the main irrigation crops of the lower-middle São Francisco Valley, i.e. beans, maize, onions, melons, rice, and, more recently, tomatoes, have rapidly increased, while that of other traditional crops such as sugarcane, cotton and manioc have not increased as quickly (Table 48).

Table 48. Area Occupied by Staple and Cash Crops in the Principal Irrigation Counties of the São Francisco River(a).

Crops(b)	1950 ha	1950 %	1979 ha	1979 %	Annual Growth Rate 1950/79(%)
STAPLE CROPS					
Beans	3525	34.5	8807	27.3	8.6
Maize	1261	12.4	6746	20.1	15.0
Manioc	2114	20.7	3536	10.9	2.3
Rice	38	0.4	599	1.8	50.9
CASH CROPS					
Cotton	2894	28.4	7436	23.3	5.5
Onions	60	0.6	4632	14.4	76.2
Sugarcane	309	3.0	380	1.2	2.3
TOTAL	10201	100.0	32240	100.0	7.4

Source of Data: Fundação IBGE (1955b, 1980).

(a) Belém do São Francisco, Cabrobó, Petrolina and Santa Maria da Boa Vista Counties.

(b) Census data for cropping area during the period under consideration are only available for these crops.

The area planted in onions has grown fastest and cash crops as a whole have increased the proportion of the cropping area they occupy, The area devoted to staples has also grown quickly. Hence the decrease in the proportion of crop land in staples from 68% to 61% does not pose a problem for the production of food stuffs. On the contrary, the annual growth rate of the area occupied by staples, 6.3%, is quite high by Northeastern standards and well above the annual rate of demographic increase in the irrigation zone, which is 4.2%.

Interviewed irrigation farmers of the study area, plant larger areas than do farmers using rain-fed cropping (Table 49). In 1976 and 1977, on average, irrigation farmers along the São Francisco River planted about 10 hectares of basic food crops as compared with 1.5 hectares in rain-fed cropping during these drought years. Irrigation farmers of the tributaries also planted more, about 8 hectares on average, in 1978 and 1979 as compared with 3 to 6 hectares for farmers practising rain-fed cropping during these years of greater precipitation.

Table 49. Average Area Planted for Private-Sector Farmers Practising Irrigation and Dry Farming in the Study Area.

Crop	Irrigation								Dry Farming(a)
	Sao Francisco River				Tributaries				
	1976		1977		1978		1979		1976-1979
	n	ha	n	ha	n	ha	n	ha	ha
STAPLE CROPS									
Beans	22	6.2	35	7.6	3	2.0	5	1.0	0.5-1.3
Maize	7	0.5	9	0.8	1	0.5	0	-	0.7-2.3
Manioc	6	2.2	7	1.8	0	-	0	-	-
Rice	10	7.3	9	3.9	3	5.7	7	7.8	1.1-2.6
CASH CROPS									
Cotton	0	-	0	-	0	-	0	-	3.2-19.6
Fruit trees	2	78.5	2	78.5	2	24.0	2	24.0	-
Melons	5	3.4	5	3.8	0	-	1	0.5	-
Onions	30	7.9	35	11.0	9	2.3	13	2.5	-
Tomatoes	0	-	7	3.2	1	0.5	2	0.4	-
Watermelons	1	0.5	6	2.0	0	-	0	0	0.1
STOCK-RAISING									
Fodders	6	43.6	6	48.3	3	2.0	7	1.7	6.9-7.1
TOTAL	30	30.1	35	34.3	10	9.9	14	10.9	4.0-18.9

Source of Data: Field Research.

(a) Sample size for dry farming as in Table 8 & 9.

The area in cash crops shows similar differences. Between 1976 and 1979, the average area of rain-fed cotton on the farms of the southern half of the study area varied from 3 to 5 hectares and farmers of the North planted about 19 hectares of rain-fed cotton. The area in irrigation cash cropping on the São Francisco River on average varied from about 16 to 28 hectares while cash crops on the tributaries occupied between 7 and 11 hectares during this period.

Production and productivity show even greater differences between irrigation and rain-fed cropping (Table 50 & 51). Generally, for most crops, the productivity of rain-fed cropping only approaches the minimum figure of irrigation in the best years. Nevertheless, even then, irrigation farmers consistently plant larger areas and attain greater overall production. Where irrigation makes the biggest difference is in cash cropping. A number of new highly productive crops are planted which, in most of the Sertão, can only be grown using irrigation. The high yields of these crops make them specially attractive to smallholders who possess modest areas of arable land.

Table 50. Average Production for Private-Sector Farmers Practising Irrigation and Dry Farming in the Study Area(a).

Crop	Irrigation				Dry Farming
	São Francisco River		Tributaries		
	1976	1977	1978	1979	1976-1979
	kg	kg	kg	kg	kg
STAPLE CROPS					
Beans	9553	6344	1000	288	87-703
Maize	2153	1400	900	-	122-711
Manioc	22500	20625	-	-	
Rice	19263	8167	5660	2612	108-913
CASH CROPS					
Cotton	-	-	-	-	1277-2217
Fruit trees	n.a.	n.a.	n.a.	n.a.	-
Melons	19600	25625	-	3500	-
Onions	115288	83952	13667	16077	-
Tomatoes	-	60800	5000	5500	-
STOCK-RAISING					
Fodders	n.a.	n.a.	n.a.	n.a.	n.a.

Source of Data: Field Research.

(a) Sample size as in Table 49.

Table 51. Average Productivity for Private-Sector Farmers Practising Irrigation and Dry Farming in the Study Area(a).

Crop	Irrigation				Dry Farming
	São Francisco River		Tributaries		
	1976	1977	1978	1979	1976-1979
	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha
STAPLE CROPS					
Beans	1541	835	500	288	124-781
Maize	4306	1759	1800	-	266-508
Manioc	10227	11458	-	-	-
Rice	2639	8167	1151	355	83-830
CASH CROPS					
Cotton	-	-	-	-	73-715
Fruit trees	n.a.	n.a.	n.a.	n.a.	-
Melons	5765	6743	-	7000	
Onions	14593	7632	5942	6431	-
Tomatoes	-	19000	10000	13750	-
STOCK-RAISING					
Fodders	n.a.	n.a.	n.a.	n.a.	n.a.

Source of Data: Field Research.

(a) Sample size as in Table 49.

The average productivity of irrigated beans, maize and rice on the São Francisco River is usually two to three times that obtained in rain-fed cropping. Similarly, the productivity of staples planted in the labour-intensive irrigation system on the tributaries is usually significantly higher than in rain-fed cropping but this is less true in years of greater precipitation. On the other hand, tributary irrigation farmers consistently plant larger areas and harvest two to three times more than in rain-fed cropping.

While irrigation is important for assuring a harvest of food crops, most farmers adopt irrigation because of its potential for cash cropping. In their view an enormous amount of high value produce is obtained through the use of irrigation. On the São Francisco River the average yield of irrigated cash crops, such as melons, onions and tomatoes, varies from roughly 6000 to 19000 kg/ha and even along the tributaries the productivity of these crops varies from about 6000 to 14000 kg/ha. In sharp contrast, rain-fed cotton only yields from 73-715 kg/ha.

The irrigation area is so productive that most farmers of the São Francisco River have virtually abandoned the interfluvial land stretching from six to twelve kilometres inland. Similarly, along the lower course of the Terra Nova River, farmers have been abandoning cotton cultivation on the interfluvial lands in order to concentrate on irrigating cash crops in the bottomlands.

Such high yields are, in part, made possible by low levels of crop loss. Traditionally, for dry farming the principal cause of crop failure or low levels of production has been the lack of regular rainfall while the role of plant disease and pests have been secondary causes of low productivity in most parts of the Sertão.

Irrigation has resolved the problem of rainfall but it has brought the problems of loss due to flooding and disease to the fore. Irrigation crops are planted close to the water courses so that any unpredictable flooding can cause harvest loss. New diseases have arrived with the new crops and planting large monoculture fields can also increase the risk of disease. Onions particularly suffer from a fungus disease, known locally as the mal de sete voltas (unidentified), which ruins the bulb. The commercial brown beans planted in irrigation are also more susceptible to fungus. Melons, tomatoes and watermelons too are delicate crops which demand greater care and use of pesticides than do rain-fed crops.

Even so, the risk of loss due to pests and disease in irrigation is low in comparison with the risk of drought in dry farming. In years of low rainfall and drought, 25-40% of the farmers practising rain-fed cropping experience harvest failure. In 1976 only 4% of the irrigation farmers interviewed experienced complete crop loss in onions, while 6% had this problem in 1977, 11% in 1978 and none in 1979. The 1977 and 1978 rate of loss was higher than the other years because of an outbreak of bulb fungus and also because a number of farmers chose not to harvest their crop given the extremely low prices at harvest time for those years. Similarly, loss of harvest in bean cropping usually affects less than 10% of the farmers and for rice cropping less than 13%. Farmers rarely experience harvest failure in the cropping of maize, manioc, melons, tomatoes and watermelons.

b) Market Orientation and Production Costs

At the same time that high productivity is achieved in irrigation through the reduction of environmental risk, market risk is immensely increased. The most lucrative crops are grown for a limited national market in which competition with other regions is fierce and these crops suffer extreme price fluctuation. The price of onions, for example, can plummet from US$ 2.69 per kilogramme to less than US$ 0.01 in the space of a month, as occurred in 1978.

One way of reducing market risk is to plant a number of different crops, and most farmers of the study area do this. Even so, nearly all the crops are planted on a commercial basis and land-owners on the São Francisco River have made the transition from peasant to capitalist farmer. This is true even for small farmers who plant a number of staple crops. These farmers also plant the same crops that are exploited on larger farms. Only a few large and very large farmers have been able to specialize in one or two cash crops and in large-scale intensive cattle raising (Table 52).

Table 52. Market Orientation according to Farm Size in Private-Sector Irrigation of the Study Area.

Farm Size	Market Orientation of Farm Activity(a)			
	Pure and Quasi-Subsistence	Semi-Subsistence	Semi-Commercial	Commercial
Small (< 10 ha)	fruit, maize, manioc, rice	beans, maize, manioc, rice	beans	melons, onions, tomatoes, watermelons
Medium (10-29 ha)	fruit	maize	beans, manioc, rice	beans, melons, rice, tomatoes, watermelons
Large (30-79 ha)	fruit	-	-	beans, manioc, melons, onions, rice, tomatoes, watermelons
Very Large (> 79 ha)	-	-	-	grapes, melons, other fruit, cattle raising

Source of Data: Field Research.

(a) Pure and quasi-subsistence farming is that where less than 25% of the produce is sold, semi-subsistence 25% to 49%, semi-commercial 50% to 74% and commercial 75% and above.

Another way of reducing market risk is by lowering the costs of production. This is done in two manners by private-sector farmers. One is through the use of an intermediate irrigation technology for more profitable cash crops and a labour-intensive or a low intermediate type for staple crops. Production costs are also reduced by using non-salaried labour. Smallholders do this by making use of family labour and medium and large farmers do this by employing sharecroppers (who also use the unremunerated labour of their family).

In fact, this flexible production strategy, where production costs are reduced through the use of different combinations of farming methods and labour inputs, makes the difference between profit and loss. If a capital-intensive technology were used profits would be seriously reduced in most years and farmers would be ruined in years of poor produce prices like those of 1977 (Table 53).

Table 53. Average Profit per Hectare per Harvest for Private-Sector Irrigation on the São Francisco River (US$).

Crop	Cost per Hectare			Gross Income per Hectare(d)	Net Income per Hectare		
	System 1(a)	System 2(b)	System 3(c)		System 1(a)	System 2(b)	System 3(c)
1976							
STAPLE CROPS							
Beans	248	77	57	1345	1097	611	1288
Maize	237	66	46	194	-43	46	112
Manioc	n.a.	n.a.	81	470	n.a.	n.a.	389
Rice	608	177	36	326	-282	4	263
CASH CROPS							
Melons	882	400	135	987	105	222	852
Onions	942	377	185	1446	504	455	1261
Watermelons	554	195	92	389	-165	34	297
1977							
STAPLE CROPS							
Beans	273	91	66	434	161	144	368
Maize	261	79	55	191	-70	34	136
Manioc	n.a.	n.a.	112	733	n.a.	n.a.	621
Rice	640	207	74	235	-405	-68	161
CASH CROPS							
Melons	870	434	158	577	-293	-13	419
Onions	937	414	234	589	-348	-16	355
Tomatoes	594	239	130	680	86	154	550
Watermelons	597	226	109	416	-181	21	307

Source of Data: Field Research.

(a) Capital-intensive system in which waged workers are used. Net income is gross income less cost.

(b) Intermediate technology system in which sharecroppers are used. Net income is gross income less costs and sharecropper's part.

(c) Labour-intensive system for staples and low intermediate technology system for cash crops. Family workers are used. Net income is gross income less cost.

(d) 1976 (n = 33), 1977 (n = 38).

Both a capital-intensive irrigation technology and a salaried labour arrangement are utilized almost exclusively on very large farms owned by outsiders. These land-owners are able to do this because they are often highly subsidized and also because they exploit certain permanent crops, such as fruit trees, and stock-raising which do not require a constant high, labour input. One of these farmers who plants melons, which do require large amounts of labour, utilizes sharecroppers and this shows that even very large farmers can use this sort of labour system if it serves their purpose.

c) Farmer Income

By adopting commercial irrigation, farmers have entered an extremely volatile national marketplace where fortunes can be made or lost. Farmers recognize this fact and compare irrigation cash cropping to playing the lottery. For example in 1976, on average, irrigation farmers on the São Francisco River made a profit of about US$ 11750 each, which is a huge sum of money by regional standards. In the following year, however, farm income was substantially less, approximately US$ 4300 on average (Table 54).

Table 54. Average Net Income per Farmer for Private-Sector Irrigation Cropping according to Farm Size in the Study Area.

Farm Size	São Francisco River				Tributaries			
	1976		1977		1978		1979	
	n	US$	n	US$	n	US$	n	US$
Small	12	2641	15	2051	9	1790	14	987
Medium	12	7314	13	4299	3	2150	3	795
Large	8	29250	9	8479	1	n.a.	1	n.a.
Very large	1	34194	1	52	0	-	0	-
All Farms	33	11747	38	4290	12	1880	17	953

Source of Data: Field Research.

Elsewhere in the developing world, large and medium farmers have the means to adopt cropping strategies which involve higher risk and generate greater income in the long run (Arnon, 1981; Gould, 1963; Pearse, 1980; Wharton, 1971). The same occurs in the study area.

Large and medium farmers respectively earned US$ 29250 and US$ 7314 in 1976 which more than offset the lower returns of US$ 8479 and US$ 4299 they received in 1977. The income of small farmers is steadier but much lower. They earned profits of only US$ 2641 in 1976, US$ 2051 in 1977, US$ 1790 in 1978 and US$ 987 in 1979. However, this occurs not because irrigation smallholders are peasants who do not wish to risk their subsistence base, but rather because larger farmers have greater access to the resources necessary for planting a larger area.

d) Land Concentration

While irrigation has allowed many farmers to earn high incomes, there is a negative side to private-sector irrigation which mirrors the development of capitalized agriculture elsewhere in the world. As Arnon (1981), Griffin (1981) and Pearse (1980) show, in developing countries, the high costs involved in capital-intensive farming naturally lead to a concentration of land ownership in fewer hands. In such places land prices soar, thereby making it difficult for smallholders to increase the size of their farms as well as tempting them to sell their land. Worsening this further in the case in study are a number of government policies which, as mentioned in the previous chapter, favour large farmers.

However, this development should not be seen as the concentration of land into latifundias. The usual notion of the idle latifundia of Latin America has come under a good deal of criticism recently. Large capitalist farms are not necessarily inefficient in Brazil (Katzman, 1984). Moreover, the distribution of land ownership in Latin American can no longer be - or perhaps never should have been - seen as merely a latifundia-minifundia dichotomy because this overlooks an important class of middle-scale farmers (Forman, 1975; Miller, 1984; Shryler, 1980; Taylor, 1984). Both points are true for the study area.

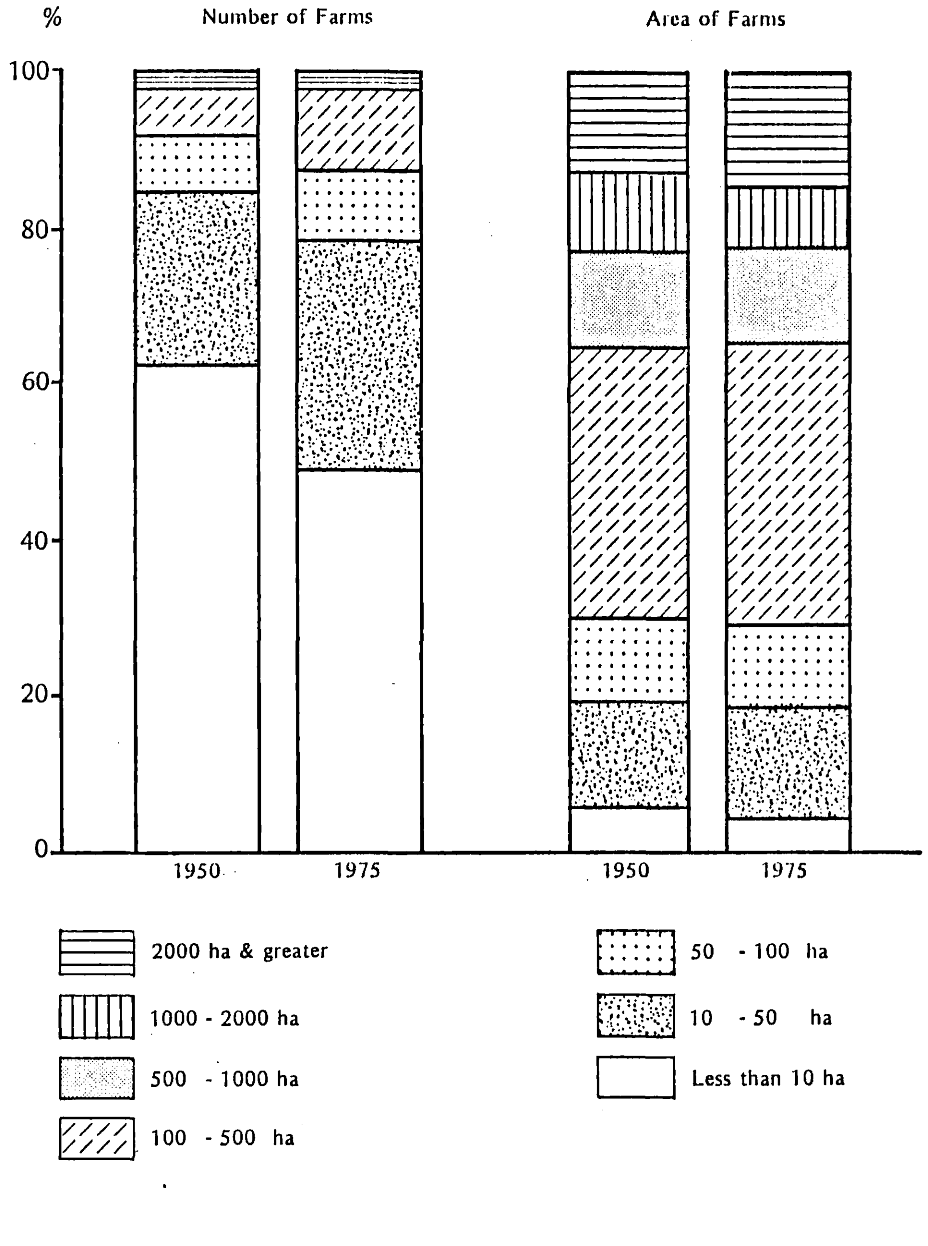
In the São Francisco irrigation counties, the number of small farms of less than 10 hectares (total farm size) has fallen from 63% to 50% between 1950 and 1975 (Figure 16). On the other hand, the number of small and medium farms in the 10-50 hectare group has increased from 23% to 30% of the total during the same period, which is not entirely an unfavourable development as some land consolidation was, in fact, needed. However, at the same time, the number of larger farms has also increased from 14% to 20% of the total. Moreover, the area occupied by the different groups did not change during this period.

This pattern of farm size for the irrigation counties is the direct opposite of that of the Sertão as a whole, where falling property size is the rule for dry farming. Land ownership has, therefore, become concentrated with the advent of irrigation and the losers have been minifundia holders who were unable to adopt irrigation. Parallel to this, a number of small farms were made economically viable and an important class of middle-scale farmers has emerged.

Public-Sector Irrigation

a) Productivity

A capital-intensive irrigation system has been established on government projects because planners hold the common assumption that the highest productivity is obtained by using such a system. Malassis (1975) has challenged this assumption and demonstrates that the type of farming system prevalent in places such as North America may be highly productive per unit of labour, but higher yields per unit of land are obtained in other parts of the world.



Source of Data: Fundação IBGE (1955b, 1979).

Figure 16. Change in the Size of Farms of the Sertão Pernambucano do São Francisco

The same occurs in the study area. Comparing Table 51 to Table 55, one sees that, contrary to what is expected by government planners, the productivity of capital-intensive irrigation of the public sector is not substantially different from that obtained in the private sector, where labour-intensive and intermediate technology is more prevalent. The productivity of beans and maize on the projects is often well below that of the private sector, while for manioc it is about the same. Capital-intensive methods only improve the productivity of rice. Similarly for cash crops, private-sector farmers produce about as many melons, onions, tomatoes and watermelons per hectare as their counterparts in public irrigation.

Table 55. Average Productivity of Public-Sector Irrigation Farmers (kg/ha).

Crops	CODEVASF(a)	DNOCS(b)	Predicted Yield(c)
STAPLES			
Beans	728	467	1400
Maize	720	454	n.a.
Rice	-	3657	6000
Manioc	-	11416	n.a.
CASH CROPS			
Cotton	-	1308	n.a.
Melons	8760	1661	11000
Onions	12000	2246	18000
Tomatoes	15250	24486	40000
Watermelons	9400	8854	18000

Source of Data: CODEVASF (n.d. 2), Diretoria Geral do DNOCS and Field Research.

(a) Bebedouro project, 1981 (n = 105).

(b) Average for all DNOCS projects, 1978 and 1980 (n = 2822).

(c) EMBRAPA Technical Packages (1976-1981).

This occurs because the main difference between intermediate and capital-intensive technology has more to do with infrastructure and labour-saving methods than with actual cropping practices which lead directly to significantly higher productivity per area planted.

Indeed, the only significant difference in terms of cropping practice is the greater use of fertilizer and pesticide. However, it appears that too much of these are used and this can actually diminish yields, either directly by stunting plant growth or indirectly by aggravating salinization.

The yardstick commonly used by planners for determining what productivity should be is the predicted yields given in EMBRAPA technical packages. When compared to these yields, agency personnel feel that yields obtained on the projects are too low (Table 55). They usually blame the capabilities of the project farmers for this, rather than consider the appropriateness of the technology which they recommend. Besides the usual complaints of this type which were heard by the researcher, examples of this are found in CODEVASF publications (n.d. 1, n.d. 4). No doubt much of the difference between what is obtained and what is expected is due to EMBRAPA exaggerating potential yields, but one suspects that environmental problems of water and soil salinity are also partially to blame.

b) Market Orientation

Government project farmers are even more market orientated than are private-sector irrigation farmers. Some staples are planted but the emphasis is on cash cropping for distant markets, though a range of different crops are planted, so as to spread risk. The specific mix of crops planted by each farmer is determined by the project co-operative or administrative personnel. Co-operative officials are agronomists and technicians, who directly or indirectly work for DNOCS or CODEVASF. They in turn receive orders from the regional and national offices concerning which crops should be planted in order to fulfil contracts undertaken with canneries, state-selected seed agencies or local and national wholesalers.

After gathering in the harvest, farmers turn it over to the co-operative for marketing. The argument is that a co-operative, or the project as a whole, can market produce on a large scale and so deal more directly with factories and big-city wholesalers. This, in turn, means that a better price should be received. Nevertheless, the average price received is not very different from that received in the private sector. It is higher for some crops, but not for others, especially those sold to canneries (Table 56).

Table 56. Average Produce Prices Received by Private and Public Irrigation Farmers (US$/kg)(a).

Crop	1976		1977		1978		1979	
	Private	DNOCS	Private	DNOCS	Private	DNOCS	Private	DNOCS
STAPLES								
Beans	0.95	0.71	0.51	0.45	0.48	0.45	0.47	0.47
Maize	0.15	0.14	0.13	0.10	0.20	0.11	n.a.	0.15
Manioc	0.09	-	0.13	-	n.a.	0.03	n.a.	0.01
Rice	0.15	0.19	0.12	0.15	0.37	0.15	0.38	0.20
CASH CROPS								
Melons	0.20	0.12	0.09	0.18	n.a.	0.13	0.25	0.11
Onions	0.19	0.23	0.13	0.20	0.16	0.28	0.15	0.16
Tomatoes	n.a.	0.08	0.15	0.08	0.27	0.07	0.17	0.05
Watermelons	0.07	-	0.05	0.09	n.a.	0.08	n.a.	0.08

Source of Data: Field Research.

(a) Sample size in the private sector: 1976 (n = 33), 1977 (n = 38), 1978 (n = 22) and 1979 (n = 28). In the public sector: 1976 (n = 1806), 1977 (n = 2303), 1978 (n = 2671) and 1979 (n = 2865).

Moreover, the size of the co-operatives has not protected them from the kind of monopolistic practices of large produce buyers that private-sector farmers suffer. The co-operatives, too, often have to wait inordinate lengths of time for payment, with inflation eroding the value of what is received. They also have been subject to unscrupulous grading practices, and, in times of overproduction, even the refusal to honour purchase contracts.

The produce of the projects is, for the most part, destined for the regional state capitals and for the Southeastern markets. DNOCS is somewhat less orientated to big-city consumer markets than is CODEVASF, and part of its produce goes to local markets and to canneries located in the Sertão or in the adjacent Agreste zone. It should be remembered that one of the government's objectives in promoting public irrigation is to resolve local food shortages caused by drought. Unfortunately, the high costs involved in both private and public irrigation force many farmers into the production of non-essential food items for markets outside the Sertão and Northeast.

c) Costs and Farmer Income

As a capital-intensive irrigation system is used in the public sector, production costs are high and this reduces profits. Like their counterparts in the private sector, most project farmers use unwaged family labour in order to reduce production costs. Nevertheless, when project farmers need outside labour they have to use waged workers so that one-third of the labour used on DNOCS projects is salaried and one half on the CODEVASF projects. Comparing Table 53 to Table 57, one sees how the high production costs in the public sector cause net income per hectare to be much lower than that earned in the private sector.

Even so, the actual income which project farmers receive, whether subsidized or not, is high by regional standards. Average income varied from about US$ 2700 to US$ 3700 for DNOCS project farmers between 1978 and 1981, while it was approximately US$ 12000 per farmer on the CODEVASF Bebedouro project in 1980 (Table 58).

As Hall (1978) also observed on the DNOCS projects which he studied, individual farmer income varies greatly. For the DNOCS projects studied here, in 1980 from 9% to 25% of the farmers lost money, 4% to 26% earned up to US$ 1000 and 9% to 26% earned between US$1000-2000. A significant number of DNOCS farmers, therefore, lose money or earn well below the average. On the other hand, in 1980 no CODEVASF farmers of the Bebedouro project lost money, only 13% earned less than half the average of US$12345 and another 41% earned between US$6150 and US$12345. The better environmental conditions of the São Francisco River probably explain why CODEVASF farmers are more successful, though, the different accounting practices of the two agencies can also influence farmer income.

Table 57. Average Profit per Hectare per Harvest for Public-Sector Irrigation (US$).

Crop	CODEVASF(a)			DNOCS(b)		
	Cost	Gross Income	Net Income	Cost	Gross Income	Net Income
STAPLES						
Beans	528	605	77	655	299	-356
Maize	602	701	99	246	97	-149
Rice	-	-	-	794	825	31
CASH CROPS						
Cotton	-	-	-	871	899	28
Garlic	2617	2990	373	-	-	-
Melons	1362	1546	184	n.a.	n.a.	n.a.
Onions	1684	1869	185	n.a.	n.a.	n.a.
Tomataoes	978	1108	130	1215	977	-238
Watermelons	871	878	7	n.a.	n.a.	n.a.

Source of Data: Diretoria Geral do DNOCS and CODEVASF (n.d. 3).

(a) Bebedouro farmers for 1981 (n = 105).

(b) Average of all DNOCS farmers for 1980 (n = 2973).

Table 58. Average Net Income per Public-Sector Irrigation Farmer.

Agency and Project	1978		1979		1980		1981	
	n	US$	n	US$	n	US$	n	US$
CODEVASF								
Bebedouro	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	105	12345
DNOCS								
Boa Vista	26	3495	27	2354	27	1716	27	3466
Custodia	48	3799	48	2773	50	7021	50	4413
All Projects	2671	2815	2865	2679	2973	3569	3028	3862

Source of Data: Diretoria Geral do DNOCS and Cooperativo Agrícola do Projeto Bebedouro.

CODEVASF farmers have larger plots than DNOCS farmers and earn a higher income. Farmer income on the CODEVASF project is similar to that of the medium farmers of the private-sector along the São Francisco River. When considering only cropping, DNOCS project farmers enjoy a somewhat better position to that of small private-sector irrigation farmers on the tributaries. However, private-sector farmers of the tributaries also exploit ranching, which DNOCS farmers do not, so their overall income is higher. Nevertheless, project farmer income is much higher than that earned in dry farming and this makes positions on the projects highly attractive for poor farmers.

It must be noted that these income figures for the public sector do not include the extremely high costs of establishing and running the projects which are subsidized by the government. For example, in 1980 alone DNOCS spent US$ 35 million on investment and operating costs for 2923 project farmers tilling 18215 hectares. This comes out to over US$ 12000 per farmer and nearly US$ 2000 per irrigated hectare, absurdly high in comparison to the income per hectare, which varied from a loss of US$ 356 to a profit of US$ 31 per hectare for all DNOCS farmers in 1980. If administrative costs are included DNOCS spends over twice this amount (Table 59). CODEVASF's operations are more profitable but not much more so, and the net return is low in comparison with the high costs of production.

Table 59. DNOCS Expenditures per Project Farmer and per Irrigated Area (US$).

Year	Average Annual Expenditure	Average Number of Farmers	Expenditure per Farmer	Average Irrigated Hectares	Expenditure per Hectare
1970-77	34 229 354	1 142	30 043	n.a.	n.a.
1978/79	36 056 329	2 679	13 459	14 600	2 470
1980	35 122 822	2 923	12 016	18 215	1 928
1980(a)	84 364 302	2 923	28 862	18 215	4 631

Source of Data: Diretoria Geral do DNOCS.

(a) This figure includes administrative costs. It was only possible to obtain this for 1980.

d) Farm Size

Up until the last few years the main aim of public-sector irrigation was to set up family farm projects. Inefficient latifundias were to be expropriated and landless peasants were to be resettled on plots meant to support family farmers. All DNOCS projects have plots of about four hectares and CODEVASF projects have plots of about ten hectares. The DNOCS plots are actually too small to support a family and at the same time avoid the long-term problem of degrading the land. This can be seen in the difficulties with low productivity and with salinization which have arisen on DNOCS projects. The amount of land available to farmers on CODEVASF projects better supports a family but the land can still be over exploited.

Plot size also does not permit sub-division for inheritance. The agencies do not allow division of plots and this is stipulated in the contract farmers sign when they enter a project. Neither of the public-sector systems, therefore, provides for the future of a farmer's children. Only one son can continue on his father's land and even then only if he satisfies the project personnel concerning his capabilities. Given this situation, and the fact that farmers have little job security, it is understandable why they invest accumulated capital in things like a car, a house and lots on the outskirts of town or even another farm away from the project. They see these as being truly theirs and as affording greater potential for their family in the long-term.

The new land rental schemes of CODEVASF represent a break with the family farm emphasis of the public sector. However, the agency has gone from one extreme to the other. What it considers small empresários on rental lands ranging from 50 to 200 hectares are in fact large and very large irrigation farmers. Moreover, encouraging agribusinesses to occupy thousands of hectares concentrates land ownership rather than makes it more equitable. In the name of technology and alleged efficiency, CODEVASF has lost sight of the original goal of redistributing land to poor Sertanejo farmers. The new policy is not a land reform programme at all but rather one of land concentration.

In sum, the use of capital-intensive irrigation methods in the public sector does not substantially raise productivity and the high cost of production means that profits are less than those earned in the private sector. Furthermore, the public sector has failed in two important objectives of its programme, i.e. in supplying staples for the Sertenejo market and in promoting equitable land reform. Instead, its efforts have merely aggravated these problems.

EMPLOYMENT OPPORTUNITY AND THE LABOUR FORCE

In contrast to dry farming, many new jobs have been created in irrigation; thus, work is provided not only for members of farmers' families but also for a large number of rural workers. This is particularly true in the private sector where the use of family labourers and sharecroppers has proved to be crucial in reducing market risk and production costs, in permitting higher farmer income to be earned and in allowing the accumulation of capital which is necessary for further expansion of production. Sharecroppers too have benefited and they earn considerably more than they would if they were waged labourers. While jobs have been created in the public sector, the use of capital-intensive technology and labour-saving devices lessens this potencial. Moreover, as waged labour is used on the government projects, and not sharecropping, workers earn lower income.

Private-Sector Irrigation

a) Labour Requirements

The introduction of irrigation has created new job opportunities and has reduced the widespread underemployment of the rural work force of the Sertão. Rain-fed cropping of cotton, corn and beans only needs from 34 to 47 man-days/hectare of work per year and stock-raising only 2 to 3. Dry farming is highly seasonal. Most work is concentrated in the short wet season and relatively little work is done during the long dry season.

This differs sharply from the manpower requirements for irrigation which, depending on the crop and the type of technology utilized, varies from 48 to 254 man-days per hectare per harvest (Table 60). Not only are more workers required per hectare but also they are employed longer throughout the year. As more than one harvest is common, the number of man-days can be two to three times higher than that of a single harvest.

Table 60. Labour Requirement per Hectare per Harvest for Private-Sector Irrigation Farmers of the Study Area.

Activity	Man-Days/Ha(a)	Workers/Ha(b)	Weeks of Work
STAPLE CROPS			
Beans	48-79	0.8-1.3	12
Maize	48-79	0.8-1.3	8
Manioc	230	1.3	42
Rice	114-148	1.1-1.5	20
CASH CROPS			
Melons	152-172	1.9-2.2	16
Onions	213-254	2.7-3.2	16
Tomatoes	144-167	1.8-2.1	16
Watermelons	89-114	1.8-2.3	10

Source of Data: Field Research.

(a) Lower figures are for mechanized production during the wet season while higher figures are for manual production during the dry season, i.e. the minimum and maximum of labour needed.

(b) 8 hours of work per day and 5 days per week.

b) The Labour Force

The traditional sharecropping type of work relations has been adapted to the new farming system because it best fits a situation of high market risk, where farmers do not intially possess much capital. Family labourers and sharecroppers still make up the bulk of the private-sector work force because the equipment necessary for irrigation is expensive, operating costs high and the crops planted suffer extreme price fluctuation. To reduce the amount of capital risked, little salaried labour is used.

Elsewhere in the Northeast and in Brazil, the adoption of capital-intensive farm methods and commercial market orientation are usually accompanied by a general monetarization of the rural economy with both inputs and outputs being paid for and sold in cash. Salaried workers are contracted on a daily, weekly or monthly basis and they are more important than the kind of workers that predominate in peasant farming, i.e. sharecroppers and family labourers (Bicalho, 1980; Ianni, 1977; Lopes, 1976; Mello, 1976; Melo, 1975; Oliveira, 1975; Sá, 1975).

However, the introduction of commercial irrigation in the study area did not cause a shift to salaried labour. This is the direct opposite of what one would expect according to the classic Leninist model of the development of capitalist agriculture (Djurfeldt, 1982; Lenin, 1982; Berstein, 1982) and is also the opposite to the type of labour relations which development planners would like to see arise. For radical and conservative social scientists alike, sharecropping in Latin America is usually thought to be a highly exploitative form of peasant work relations and the shift to waged labour relations is considered to be better for workers (Feder, 1971; CIDA, 1966).

In recent years sharecropping has been reassessed and it is no longer considered to be an inherently-exploitative and economically-inefficient form of labour relations, found only in pre-capitalist agriculture (Cheung, 1969; Jones, 1982; Loureiro, 1977; Martinez-Alier, 1983; Newbery, 1975; Reid, 1973; Stiglitz, 1974). Indeed, Martinez-Alier holds that sharecropping can not only survive in a period of capitalist development in agriculture, but can emerge and even flourish under this system. Loureiro (1977) arrived at a similar conclusion for commercial farming in the Central-South of Brazil.

In the São Francisco irrigation zone, the proportion of the labour force made up by sharecroppers has increased somewhat when it has been decreasing in the rest of the Sertão. Of the total work force, 2.7% consisted of sharecroppers in 1950 while 3.4% did in 1975. During the same period, family workers increased from 82% to 90% of the work force and day-labourers fell from 14% to 4% (Fundação IBGE, 1955b, 1979). Today, therefore, more non-waged labour is being used than before, despite the shift to capitalized agriculture.

When analysing the labour input on the irrigation farms of the study area, one sees the importance of family workers and of sharecroppers (Table 61). Family workers are more important on small farms and fairly important on medium farms. Only very large farms hire more waged labour than family and sharecropper labour.

On most farms, it is only necessary to contract extra workers during the peak of farm activities, such as planting and harvest time. However, the temporary day-labourers hired on such occasions are almost all sharecroppers from neighbouring farms or family members of resident sharecroppers. Indeed, a sharecropper who is exclusively a sharecropper is a rarity. Almost all work as day-labourers when not occupied in their fields. Also, their family members employ themselves as part-time workers to increase their overall income. This work can be a very important source of income in years of low produce prices. In 1976 and 1977 for example, wage labour represented about a third of the income of 22 interviewed sharecroppers while in other years it only represented from 13% to 18% of the total.

Table 61. Type of Labour Used Annually according to Farm Size for Private-Sector Irrigation on the São Francisco River (1977).

Farm Size(a)	Family Labourers	Share-croppers	Salaried Employees	Day-Labourers	Total	
	%	%	%	%	man-days	%
Small	63.3	16.7	0	20.0	750	100
Medium	9.7	49.1	3.5	37.7	2850	100
Large	0.5	56.8	3.5	39.2	9375	100
Very Large	0.2	9.1	14.8	75.9	33725	100

Source of Data: Field Research.

(a) Small farms (n = 9), medium (n = 17), large (n = 10), very large (n = 3). Farm size is defined in Table 36.

Despite the fact that sharecropping has been the traditional system of mobilizing non-familial labour in the Semi-Arid Zone and continues to be used today in irrigation, the system used in irrigation is somewhat different from that used in dry farming. In irrigation the land-owner determines what is to be grown and supplies all the material for cultivation. Quite frequently the owner even provides a weekly cash advance which pays for food needs until the harvest.

When calculating the sharecropper's part of the harvest, the advance and some of the costs of production are deducted from the amount of money received from the sale of the harvest. Only then is the remainder divided between owner and sharecropper. The weekly advance represents a greater outlay of money on the part of the owner. When a loss is incurred, it amounts to paying partially for the cost of labour, thereby raising overall costs and loss. So the owner feels that more risk is involved and the sharecropper is forced to assume a larger part of the costs of cropping when the final division of profits takes place.

Is this new type of sharecropper to be considered as a tenant farmer or a disguised waged worker? Morgan and Munton (1971) consider sharecroppers to be a kind of tenant farmer who pays rent in product but who is also similar to a waged worker, for the landlord often provides the equipment, accommodation and even livestock. On the other hand, sharecroppers, unlike salaried workers, are exposed to the risks of production as tenant farmers. Loureiro (1977) identifies three types of sharecropper in Brazil, each of which is distinguished by the degree of independence that he has in going about his work and in disposing of his produce. One type is totally autonomous and his situation is similar to that of a true tenant farmer. The second type has only partial autonomy. The third has little freedom of action and resembles a salaried worker.

The sharecroppers in irrigation belong to this last type, i.e. they bear a strong resemblance to wage earners and the weekly advance is very similar to a salary. However, the advance is not thought of as a wage but rather as a loan which is deducted from their part of the proceeds of the harvest. Moreover, unlike waged labourers, sharecroppers run the risk of loss as well as the chance of substantial profit. If they lose money a number of times consecutively and accumulate a large debt, either they flee the farm or the owner asks them to leave so as to avoid any further losses. In either case the sharecropper has no further liability to the land-owner, for the latter is interested more in profit than in tying workers to the land. A sharecropper who flees a debt can still find work on another farm. He is not blacklisted, for everybody involved realize that loss is often a result of low market price or plant disease and not necessarily the fault of the worker.

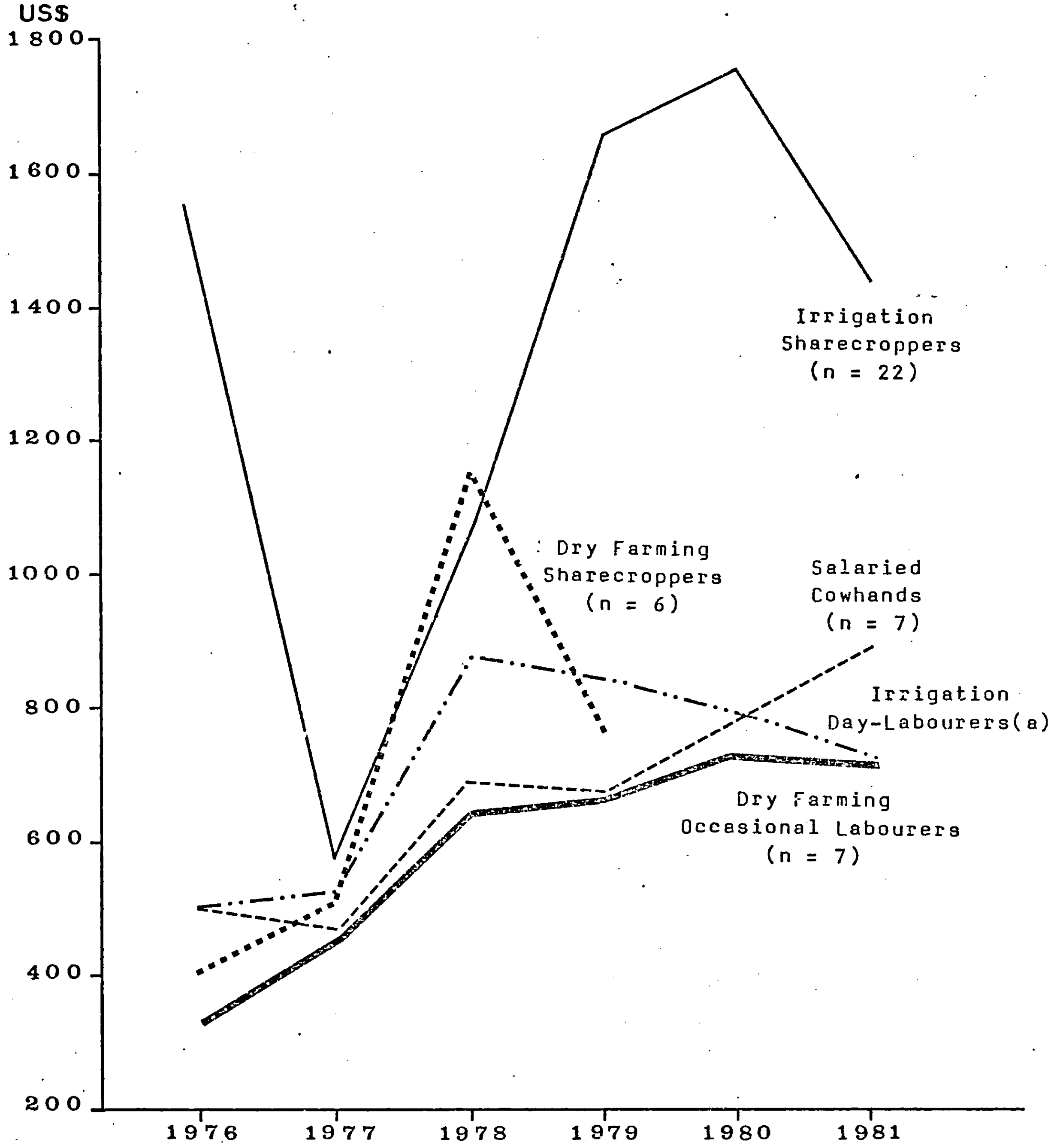
So, today, there is a tendency for irrigation sharecroppers to take on aspects of a salaried worker and a tenant farmer. The calculations of payment are made in money, not in produce. Payment itself is thought of as being half of the profits, which is the amount received upon sale of harvest less the costs of production, and not half of the produce itself. The buyer of the sharecropper's part is usually the same as the one who purchases the owner's part and is not the owner himself, as in dry farming. On the other hand, many of the older social relations of mutual obligations between patron and retainer are still in force. The owners realize that they have to maintain a personal relationship with workers if the latter are to work properly. This is in keeping with a peasant society in transition.

c) Worker Income

Income for irrigation sharecroppers of the Sertão can be uncertain and a loss may be incurred, but the usual situation is for a profit to be made at harvest time which, counted together with the weekly advance and wages earned from working occasionally as day-labourers, adds up to better pay than would be received by specialist day-labourers if the latter could find work regularly. Sharecropper income also compares favourably with that of other rural workers of the Sertão and is usually two to three times higher (Figure 17). Also, their income is ordinarily higher than the so-called minimum wage, which was US$ 717 annually in 1978. This wage is really only paid to industrial workers of the Northeast and rural wages are normally well below this figure throughout most of the region.

While income for workers in dry farming is principally affected by drought, that of irrigation sharecroppers, to a large extent, varies according to fluctuations in crop price. However, even in years of low prices, the income obtained from the weekly advance and from part-time work as day-labourers gives irrigation sharecroppers a higher monetary income than would be received by a full-time salaried worker in irrigation or in dry-farming.

One serious problem that irrigation sharecroppers have in common with day-labourers is the lack of a subsistence base. Subsistence production represents less than 10% of the total income of irrigation workers while it is very important for workers in dry farming, being the equivalent of from 20% to over 50% of their income. Irrigation farming is mainly specialized in cash crops. Beans are the only food crop planted by most sharecroppers. Also, as fields are larger in irrigation and production is undertaken throughout the year, there are



(a) Hypothetical case.

Source of Data: Field Research.

Figure 17. Average Annual Income of Farm Workers of the Sertão.

few fallow areas in which workers can pasture their animals. The weekly advance is given to resolve the subsistence problem for it permits sharecroppers to purchase the food stuffs they need until harvest time.

Public-Sector Irrigation

a) Labour Requirements

Extravagant claims are usually made in government plans for the creation of jobs in public-sector irrigation. A good deal of employment is generated by the projects, but most is in administration rather than in farming itself. Most of the jobs are concentrated in the medium and large cities of the Northeast and not in the interior.

In 1980 DNOCS spent about US$ 84 million for its irrigation programme. Of this, US$ 42 million were spent to support the Central Administration Office in Fortaleza and another US$ 7 million paid the expenditure of the four regional administrative offices and the adminstration of 25 projects. In other words, half the budget went to pay the expenses of central administration, about 9% for regional and local administration of the projects and only 41% of the total actually went to operating and investment costs on the projects. Obviously, this is a programme which creates more urban employment than positions for irrigation farmers in the interior. This is typical of economic planning in the Northeast, where politics and nepotism fill huge buildings with bureaucrats whose main output is paper rather than real development. This, combined with the urban-bias of Brazilian development in general, causes the concentration of these jobs in the state capitals and in Brasília. So, the Sertão receives little direct benefit from the enormous expenditures made in public-sector irrigation.

Even the agricultural employment generated is limited by the nature of the programme. As the public-sector irrigation system must be 'modern', it is necessarily capital-intensive. This means that elaborate infrastructure works are made and mechanization is used whenever possible in farming. The planners did not stop to think if these labour-saving devices were necessary or even appropriate in a region where a surplus of labour is available and unemployment is perhaps the greatest problem. As a consequence, DNOCS projects employ one farmer family and one permanent employee per 4-5 hectares cultivated per harvest. On the CODEVASF Bebedouro project, one farmer and two permanent employees are employed per 10-12 hectares per harvest. More labour-intensive systems are used in the private sector and as a result one family tills about 1-1.5 hectares per harvest.

b) <u>The Labour Force and Worker Income</u>

Government planners tend to view sharecropping as backward and exploitative. CODEVASF (n.d. 1) gives this as a principal reason for establishing its projects in areas where private-sector irrigation already exists. According to this view, sharecroppers become project farmers and no longer have to pay half of their production as rent. Similarly, Hall (1978) reports that DNOCs became disillusioned with earlier joint ventures with large private-sector farmers because these were absentee landlords whose farms were worked by landless peasants on a sub-letting or production sharing basis. Today project farmers are not allowed to sub-let their land or employ sharecroppers and additional labour needs are fulfilled through the use of 'modern' waged labour.

The main source of labour used on <u>family farmer projects</u> is, indeed, that of the farmers themselves and their immediate family members. DNOCS plots are small and most work is done by the farmer's family but a third is supplied by waged labour. CODEVASF plots are larger so that about a half of the labour needs must be met with outside workers. The input of family labour is not higher because project farmers, like medium and large private-sector farmers, have high aspirations for their children. As a consequence, many are at school and so not available to help in the fields.

There are two types of outside labour contracted by project farmers: permanent and seasonal workers. Most DNOCS farmers contract one full-time labourer throughout the year. CODEVASF farmers usually have two of these workers. Besides this, day labourers are hired at harvest time.

The salary paid to both kinds of worker is higher than that paid in dry farming. In 1978 field hands on the CODEVASF Bebedouro project earned US$ 3.76 per day while the rate for day-labourers in dry farming was only US$ 2.41. However, the CODEVASF wage is high because this is the rate for day-labourers in private-sector irrigation along the São Francisco River. The wage in the private sector is higher than that of dry farming because of the large demand for labour in irrigation. So in terms of this kind of worker the private and public sectors pay the same. However, waged labour is not the most common form of contracting labour in the private sector. Sharecropping is and, as was shown before, this kind of worker earns much more than does a waged labourer. Workers in the private sector, therefore, are better remunerated than in the public sector.

With respect to outside field labour, CODEVASF's new <u>rental scheme for large farmers and agribusinesses</u> are supposed to operate under the same conditions as the older family farmer system. Salaried labour is to be used and all the requirements of the labour laws are to be observed.

One of the two large farmers renting land on the Bebedouro project tried to use a salaried labour system. He ran into difficulties both because he made deductions from wages which the workers thought to be unjust and because the labourers did not like a waged system. As a result the tenant farmer switched over to sharecropping which pleased his workers but annoyed the project personnel. This shows that local workers do not find wage labour attractive and that large landholders find sharecropping a more manageable system for crops with higher labour inputs.

SOCIAL DISPARITY AND SOCIAL MOBILITY

The introduction of irrigation has enabled farmers and workers to earn greater incomes than in dry farming. This has resulted in a higher standard of living for irrigation farmers but less so for irrigation workers. Greater social disparity usually accompanies the introduction of capitalized agriculture and the process of rural development in the less industrialized countries (Arnon, 1981; Brookfield, 1979; Griffin, 1981; Harvey et al., 1979; Pearse, 1980; Smith, 1979).

While unequal access to the means of production is at the root of the growing social disparity in the study area, the slower rise in the standard of living of private-sector irrigation workers is also related to their high rates of saving. Sharecroppers prefer to accumulate capital rather than spend their income on consumer items. They do this in an attempt to become independent farmers. The development of private-sector irrigation thus carries the peasant along with it in the way that Pearse (1980) talks of rather than marginalizing him as is usually the case in Latin America.

As the labour system utilized in the public sector is based on wages, less income is earned than sharecroppers receive in the private sector. Consequently, the standard of living of project field workers is lower and less upward social mobility occurs. The introduction of public-sector irrigation, therefore, results in greater social polarization.

Private-Sector Irrigation

a) Social Disparity

Irrigation land-owners have raised their standard of living significantly in comparison with owners who practise dry farming and the larger the farm, the greater has been the relative rise in the standard of living. Utilizing an index of social dispariy (see Appendix 3), one sees that small irrigation farmers rank 34.3 on the scale while small land-owners in dry farming rank 24.5. Large irrigation farmers reach a value of 72.9 versus 58.0 for large land-owners in dry farming (Table 62).

Living conditions, too, are somewhat higher for irrigation sharecroppers than for other rural workers of the Sertão but not significantly so. The standard of living of irrigation sharecroppers is better than that of other workers in terms of housing and house possessions but not in the method of transport, in schooling and diet. The low index value for diet reflects the loss of a subsistence base which results from sharecroppers being forced to specialize mainly in cash crops.

However, not all - or even most - of the higher income earned by irrigation sharecroppers is spent on purchasing food. Much of the income is saved and rates of saving for sharecroppers reach 21% as compared to only 4% for dry farming workers. Harvest money is invested in such items as a house or land in town and in livestock.

The livestock are placed on a relative's farm outside the irrigation zone.

Table 62. Index of Social Disparity between Different Types of Farmers and Workers in Irrigation along the São Francisco River and in Dry Farming(a).

Rural Type	n	House	House Furnishings	Education	Transport	Diet	INDEX VALUE
IRRIGATION							
Workers	17	35.0	16.7	13.5	10.0	15.1	18.8
Small farmers	16	57.2	31.0	23.4	20.6	34.8	34.3
Medium farmers(b)	12	79.2	60.0	40.1	33.0	60.8	51.2
Large farmers(b)	10	95.5	82.9	57.0	66.1	70.3	72.9
Very large farmers(b)	5	97.0	100.0	100.0	80.3	n.a.	94.3
DRY FARMING							
Workers	23	28.8	16.3	11.7	11.8	19.9	17.6
Small farmers	28	44.2	19.9	18.4	20.2	18.1	24.5
Medium farmers(b)	21	53.2	36.0	31.3	26.7	46.8	38.8
Large farmers(b)	13	71.4	58.7	55.9	35.8	66.6	58.0

Source of Data: Field Research.

(a) Index value per observation is the average of the indicators House, House Furnishings, Education, Transport and Diet. Each indicator is scale from 0, the minimum condition, to 100, the maximum.

(b) Many medium, large and very large farmers usually have other professions, which can be important sources of income, so raising their index value.

Nevertheless, the standard of living of irrigation farm owners has risen rapidly so that social disparity between irrigation workers and owners has increased with the advent of irrigation. While the lowest situation in the dry farming is that of moradores at 17.6 on the social disparity index, large farmers only reach a level of 58.0. In irrigation the extremes are 18.8 and 94.3. Even excluding the very large farm owners, many of whom are absentee landlords residing in the large cities of Brazil, the standard of living for large irrigation farmers, who are local people, is still very high in comparison with the lot of the sharecroppers.

Quite simply, the large farmers are becoming richer at a faster rate. This trend supports such recent critics of the process of rural development as Arnon (1981), Brookfield (1979), Griffin (1981), Harvey *et al.* (1979), Pearse (1980) and Smith (1979) who contend that, in the first stages of development, social disparity becomes worse and particularly in the rural zone of Latin America.

b) Upward Social Mobility

Despite rising disparity, considerable opportunity for upward social mobility exists in irrigation. Utilizing a distinction that McGuire & Netting (1982) make for Swiss peasants, the disparity between social strata in the irrigation zone may be widening but mobility between the strata has also increased. Mobility exists because sharecropping is used and not salaried labour. Admittedly, only a limited number substantially improve their social position, but it is this hope which motivates those involved.

When a good harvest is gathered in at a moment of large profits, a sharecropper can quickly enter into a cycle of capital accumulation whereby he passes to tenant farmer status, and finally, to land-owner. First, he buys a pump and rents land. As he only pays 10% of the value of the harvest to the land-owner for rent, his chances for accumulating enough capital to purchase land are good. Of the 16 tenant farmers interviewed on the São Francisco River, 44% had been sharecroppers previously and of the 38 land-owners 13% had been sharecroppers at some point in their lives. A few of these land-owners are now medium and large farmers. Various sharing arrangements also allow some small land-owners to gain access to irrigation water in order to work their own land and finally to accumulate enough capital to buy a pump.

No interviewed sharecroppers were encountered who had previously been land-owners along the São Francisco River. On the other hand, some cases were encountered where the present land-owners bought out small farmers who moved to town or emigrated. The former owners were most likely tempted to sell their farms because of the high price of land in the irrigation zone. Nevertheless, there are probably more - or at least as many - workers moving up as there are farm owners of this type leaving agriculture.

The model of social mobility which best fits the situation of private-sector irrigation is Shanin's (1982) multidirectional mobility type, i.e. farmers move up and down. This is different from most other parts of Brazil and Latin America where only medium and large farmers improve their relative standing, while most small farmers and workers sink into a pauperized mass of proletarians, as in Shanin's centrifugal model of social mobility or in Lenin's Junker model of capitalist development in agriculture (Figure 18).

Proletarianization has not occurred because of the sharecropping system. Contrary to Lenin's model, in the study area, all types of land-owner and even landless peasants can move up, not just a few rich peasants. Otherwise, waged labourers in the dry farming of the Sertão, be they cowhands or crop workers, are stuck in their place and are incapable of amassing the capital necessary to make the transition from wage earner to farm owner. Their salary merely covers subsistence needs and they never receive a large lump sum of money, as a sharecropper can, which can subsequently be used for investment. At best, salaried workers in dry farming can save a modest amount of money every week or month, which can never grow into any significant investment fund, for it is ravaged by the galloping inflation of Brazil. They can only improve their situation by leaving agriculture altogether.

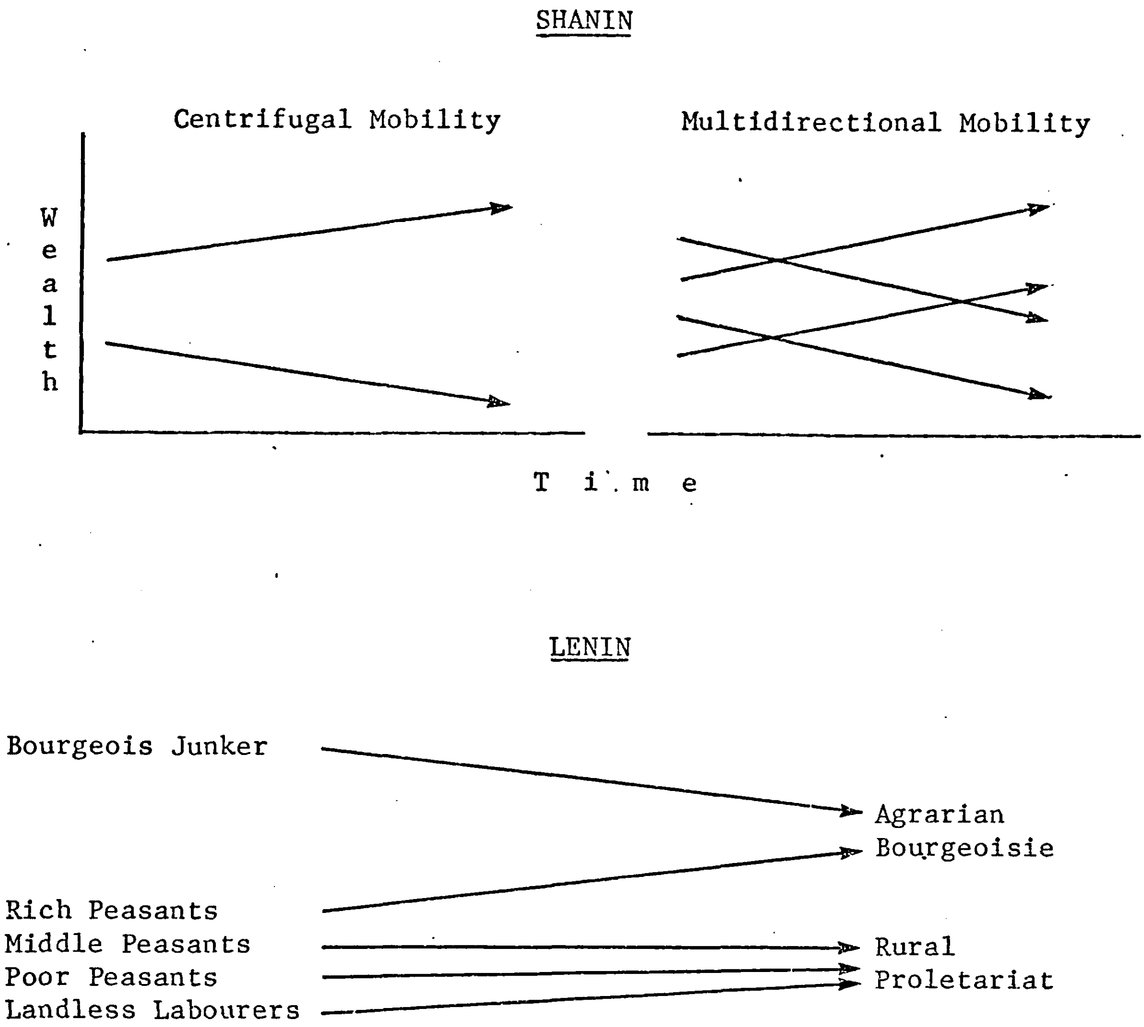


Figure 18. Shanin's (1982) and Lenin's (after Djurfeldt, 1982) Models of Social Mobility in Capitalist Agriculture.

Public-Sector Irrigation

As most project farmers were previously landless peasants, their standard of living rises substantially when they enter a government project. Their present situation is similar to that of small and medium irrigation farmers of the private sector. The 142 DNOCS farmers on the Boa Vista and Moxotó projects researched attain a social disparity index value of 34.8, while 105 CODEVASF farmers of the Bebedouro project (n = 105) have a value of 48.9.

When farmers enter a project they receive a house along with their plots. The house is of good quality, but the farmers do not feel that it is actually theirs. They do not make many of the improvements that farmers of the private sector do when their income rises. Instead, project farmers prefer to purchase a house in town for their children to use when they study, or as a place for the family to go to if the farmer has to leave the project. Consequently, project personnel complain that the project houses are not maintained properly. The farmers, on the other hand, feel that the project should do all repair work on the house and, in some cases, that even such house items as light bulbs should be supplied by the project. This occurs because of the unstable and dependent relationship instilled by the project personnel. Otherwise, behaviour in respect to the standard of living seems to be similar to that of equivalent private-sector farmers.

The standard of living of 17 workers on the Bebedouro project registers only 16.7 on the index of social disparity used, which is worse than that of their sharecropper counterparts in private-sector irrigation. These workers suffer nearly the same fate of marginalization and proletarianization - called the bóia-fria syndrome - as other waged rural labourers in Brazil. Some CODEVASF workers live in the equipment shed of the farmer for whom they work. This may be a brick building but that is about all. It consists of merely one large room with no living facilities of any kind. The workers often have to live with another family and, worse, with dangerous pesticides. Some workers complained of the terrible smell in these sheds. Other workers live in simple wattle-and-daub houses on the outskirts of the project or in nearby hamlets. Some cases were encountered of workers living in dwellings made of discarded plastic pesticide sacks.

As mentioned before, a lucky few pass through an apprenticeship whereby they become project farmers but most new positions go to the children of project farmers. Given the fact that only one son can inherit the family plot, it makes good sense to favour the children of project farmers. On the other hand, this practice only further hardens the social structure of the projects. The vast majority of project field hands never rise above a harsh proletarian existence. Most probably emigrate elsewhere in search of better work.

MIGRATION PATTERNS

The introduction of irrigation has resulted not only in higher income, greater chances of social mobility and a higher standard of living for most farmers and workers, but it has also opened up greater opportunity for work than existed in the previous dry farming system. All these factors have caused high population growth in the São Francisco River area. This has been accomplished both by fixing the population that would otherwise have emigrated and by attracting people from neighbouring non-irrigation areas and even from some distant points of the Sertão or beyond.

Private-Sector Irrigation

The demographic growth of the irrigation counties of the lower-middle course of the São Francisco River has been increasing at an unprecedented rate for the rural Northeast. From 1950 to 1980 the annual rate of population increase for these counties averaged 4.2%. The demographic growth rate for Floresta, a nearby dry farming county, was only 1.8% for this period. For the same period the increase for the rest of the Sertão was 1.8% while for the whole of the Northeast the rate was 2.3% (Fundação IBGE, 1962, 1972, 1981).

Magnanini (1977) and Moura *et al.* (1975) argue that much of this population increase was a function of the urban growth of Petrolina.

Furthermore, Moura et al. note that the rural zone of this area is one of the few in the Northeast which is experiencing fast population growth rather than stagnation or decline. They attribute this to the various SUDENE and CODEVASF sponsored irrigation projects in the area. Petrolina has indeed grown rapidly but so have the other cities of this area. Furthermore, it is hard to see how projects employing a few hundred farmers and workers have caused the rural population to increase so much.

With the exception of the growing industrial and service sectors in Petrolina, the expansion of private-sector irrigation has been the principal cause for the rapid population growth of the counties studied. The growth of the small cities of the irrigation zone and the expansion of commerce and services have been generated by the booming primary sector. In stark contrast with the demographic patterns in the rest of the Northeast, the rural population increased at a rate of 3.0% annually from 1950 to 1980 in these counties. Similarly, workers employed in the farm sector increased by 5.5% annually between 1950 and 1980 while the increase in the rest of the Sertão was only 1.2% annually for the same period. Furthermore, in 1980, the proportion of the work force employed in agriculture in Belém do São Francisco County was still 63% of the total while in the rest of the Sertão farm workers had fallen to 52%. In the irrigation counties all these trends are related to a rapid increase in irrigated area which expanded at a rate of 6.8% per year from 1960 to 1970 and 10.5% from 1970 to 1975 (Fundação IBGE 1955a, 1966b, 1979, 1981, 1983).

Much of the increase is due to an influx of outsiders and the irrigation counties have some of the largest proportions of non-native to native inhabitants in the Sertão. In 1980, 24% of the population of these counties was made up of outsiders who had moved there less than ten years ago. In dry farming counties of the study area, outsiders usually make up less than 10% of the total population (Fundação IBGE, 1983).

Most migrants are drawn to work on irrigation farms. Those who arrive with capital become tenant farmers or land-owners. Of the 38 irrigation farmers interviewed, 47% were born off the São Francisco River (Table 63). The majority of migrants, though, do not bring capital and they become sharecroppers.

<u>Table 63. Place of Origin of Irrigation Farmers and Workers along the São Francisco River.</u>

Place of Origin	Private Sector				Public Sector(a)	
	Sharecroppers		Farmers		Farmers	
	n	%	n	%	n	%
Irrigation zone	16	21.1	21	51.2	31	30.4
Nearby dry farming zone	25	32.9	12	29.3	11	10.8
Distant dry farming zone	34	44.7	2	4.9	53	51.9
Other zone of Northeast	1	1.3	0	-	5	4.9
Northeastern capital	0	-	3	7.3	0	-
Southeastern city & abroad	0	-	3	7.3	2	2.0
Total	76	100.0	41	100.0	102	100.0

Source of Data: Field Research.

(a) Family farmers and operational leasees of the Bebedouro project.

Different kinds of farmers present different migration trends. As would be expected, new arrivals and upwardly mobile older immigrants buy small and medium-sized farms. They come from neighbouring dry farming areas. No large farmers are outsiders. They are local people who are either descendants of large land-owners or were medium farmers who increased the size of their farm and have risen in life. Very large farmers, on the other hand, are mainly outsider investors who reside in other zones of the Northeast or even in other regions of Brazil. One is a foreigner. They find the area to be one of great speculative opportunity.

Of the 76 sharecroppers interviewed concerning their place of origin, 70% were found to be immigrants and 30% were born in the area along the São Francisco River. The interviewed sharecropper with the longest residence in the zone arrived in 1959, when irrigation was in its first phase of expansion. During the 1960s the number of immigrants increased and their date of arrival is spread evenly over the years of that decade. During the 1970s the influx became more rapid and the early 1970s saw the greatest number arrive.

The reasons given by sharecroppers for leaving their place of origin for the irrigation zone usually involve the lack of opportunity and difficulties of life where they previously lived. In the long-term, they see the chance for a better lifestyle on the São Francisco River. Of the motives given by 14 interviewed sharecroppers for immigration, 57% wanted an easier way of life on the river where water is plentiful and drought is not a problem, 22% were attracted to the area because of the better prospectives for earning a higher income, 14% came in order to find work and 7% moved there because they genearally considered the river area to be a better place to live.

Having made the move of the 16 sharecroppers who were interviewed concerning what they think of their present situation, half thought themselves to be better off for it, 31% considered their situation to be the same as before. The rest held the view that they were worse off, 13% because of their lack of success in irrigation and 6% due to the greater effort and worry involved in their new work.

The rural transformation of these counties also offers greater prospects for children of farmers and workers. Of 102 interviewed families in the rural and urban zone of Belém do São Francisco County, only 17% of their children had emigrated from the Sertão as compared to 27% and 29% respectively for the dry farming counties of Chorrochó and Parnamirim. In Belém, only 3% of the children of irrigation workers have emigated from the Northeast all together as compared to 22% and 23% respectively for rural workers in Chorrochó and Parnamirim. Moreover, the children of middle and upper class of Belém who leave the Sertão go to upwardly mobile jobs in the state capitals. This occurs because high incomes permit many more children of the irrigation zone to study in the capital than do children of dry farming zones. 'Irrigation, therefore, offers greater opportunity in both the short-run and in the long-run.

Public-Sector Irrigation

The same cannot be said of public-sector irrigation. In the study area, the projects installed roughly the same number of farmers as were removed to make way for the projects. In zones of the Sertão where more cropping is practised, many more farmers leave the expropriated areas than are resettled there. Hall (1978) calculates that three to six times as many families left than were settled on the three DNOCS projects that he studied in Ceará and Paraíba States. This occurs because in these places, the more favourable environmental conditions historically allowed for a greater number of landless peasants and small land-owners to be present. It is this kind of farmer who is most often removed in order to make way for the projects. This only worsens rural exodus so, contrary to their stated purpose of reducing emigration, the agencies either only resettle as many farmers on the land as they remove, or worse, they are a new cause of emigration.

The demographic and employment trends of Icó and Morada Nova Counties in Ceará State clearly demonstrate this. Two of DNOCS's largest projects are located in these counties and the urban zones of the two counties are small. Hence, the two are a good test of the impact of public-sector irrigation. Between 1950 and 1980 the annual rate of overall population growth in Icó and Morada Nova was 1.4% and 2.6% respectively. Population growth in Icó was below the average for the Sertão, 1.8% annually and the rate for Morada Nova was above the average. However, the growth rates of both are still well below the rate of 4.2% for the São Francisco area.

Growth in farm jobs increased at a rate of 1.7% and 2.4% per year in Icó and Morada Nova between 1950 and 1980 which was above the Sertanejo average of 1.2% per year but again well below the 5.2% rate in the São Francisco counties. Furthermore, overall unemployment increased sharply from 8% to 34% in Icó and from 11% to 30% in Morada Nova during this period as compared to an increase of 16% to 20% for the whole Sertão. Quite clearly, the projects did not resolve the job problem, they have only made matters worse.

Furthermore, the jobs created go to outsiders. For example, nearly 70% of the farmers on the Bebedouro project come from counties other than those in which the project are located. Most arrived in the vicinity of the project after 1970. The ones that came before that date had been drifting from place to place in search of work since the early 1960s.

Despite the fact that the expansion of public projects is controlled by government decisions from the federal and regional level, the influx of outsiders to public projects occurred at the same time that it happened on the private-sector farms. So looking at the irrigation zone of the lower-middle São Francisco River as a whole, it is possible to identify the early 1960s as the initial period of migrant attraction. As irrigation expanded in the 1970s its growing demand for labour coincided with a period of prolonged drought so that factors of attraction and expulsion drew the rural poor of dry farming zones to the irrigation area.

Irrigation, therefore, has enabled larger areas to be planted. Larger harvests are consistently gathered in. More people, in turn, are employed full time in irrigation than in dry farming. They earn higher incomes. Irrigation farmers and workers improve their standard of living and, in some cases, individuals of modest origin can raise their social position. Private-sector irrigation does this better and the migration patterns show this. A large contingent of new farmers and workers have been attracted to private-sector irrigation, which has not been the case in the public sector.

9. IRRIGATION AND RURAL CHANGE IN THE SERTÃO

In this study, a detailed analysis has been made of attempts to introduce a new farm production system into an underdeveloped semi-arid region. Irrigation is found to overcome long-standing problems of drought, unemployment, underemployment, low productivity, poverty and rural exodus.

Private-sector irrigation is shown to do this better than public-sector irrigation. This occurs because a model of development from below at the periphery has arisen in the private sector. The greater flexibility in the combination of production factors in this system allows a larger number of farmers to adopt irrigation and results in a system which is better adapted to the varying local environmental and socio-economic conditions of the Sertão. More full-time jobs are created, higher income is earned by both farmers and workers and upward social mobility is greater than in the public sector. The inflexible introduction of capital-intensive irrigation in the public sector is part and parcel of the top-down, urban-industrial biased model utilized in government economic planning. The result is a system which more often aggravates the environmental and socio-economic difficulties of the Sertão rather than solves them.

With respect to the first proposition, formulated in Chapter 1, local and national factors severely limit technical intensification in dry farming and so restrict its capacity to overcome Sertanejo problems. Rain-fed cropping has been particularly depressed by a combination of low produce prices, declining farm size and the general inappropriateness of most new cropping methods for underdeveloped semi-arid zones. Cattle ranching has experienced some change, in response to reasonably good prices and to the introduction of appropriate technical innovation, but the system has not changed fast enough to counterbalance increasing population pressure and rising consumer needs. Furthermore, both cropping and stock-raising remain highly vulnerable to drought. This was especially apparent during the recent prolonged drought. Not only was harvest failure widespread and herds devastated but the process of introducing innovations was also set back.

Irrigation, on the other hand, has experienced rapid technical change, harvest failure is rare, and production and productivity are much higher than in dry farming. Irrigation farmers are able to plant more staples and exploit lucrative cash crops which cannot be planted using dry farming. Greater income is earned, much of which is reinvested in further technical innovation. Most irrigation systems require large quantities of labour so that four to ten times as many workers are needed per hectare annually. Numerous jobs have thus been created which employ local people and immigrants from neighbouring areas of depressed dry farming.

However, environmental conditions limit the scale of irrigation in the Sertão. Salinization is a serious problem throughout most of the zone. This means that few places exist where specialized irrigation can be practised and that capital-intensive methods should be avoided even in these places. In fact, irrigation has to be exploited in association with dry farming in most of the Sertão. Where more and better quality soils and water are available, irrigation can be exploited on a larger scale and so can be of greater importance in the whole farm system in these places. Where environmental conditions are less favourable for the practice of irrigation, dry farming activities are of greater importance.

With this in mind, the Sertão can be zoned with respect to the type and scale of irrigation that can be exploited in different places. This roughly follows the dry farming zones described in Chapter 4, which also correspond to varying availabilities of the soil and water resources necessary for the practice of irrigation.

Irrigation should be limited in scale in drier stock-raising zones where soils are poor. In these zones, large-scale cash cropping is impractical and irrigation could aid ranching by furnishing fodder. As natural conditions improve, more cropping can be undertaken and irrigation can gradually assume greater importance as one moves from drier to more humid areas with better soils and water supply. In highland zones, where rain-fed cropping is more reliable and amenable to change, can irrigation complement rain-fed cropping and improved stock-raising as it does in parts of the world where precipitation is greater and more evenly dispersed.

However, throughout most of the Sertão, the nature of soil and water resources limit the amount of irrigation cropping which can be exploited so that stock-raising and rain-fed cropping will continue to be the mainstay in most of the zone. Technical innovation must, therefore, take place in whole farming systems and cannot be limited to irrigation. The hard task of improving dry farming must be undertaken and this calls for considerable restructuring of government economic policy and efforts to promote change in the Sertão. Otherwise, islands of prosperity arise in the few places where irrigation can be practised on a larger scale while the rest of the Sertão remains mired in poverty.

The question of scale and technology type thus assumes paramount importance, which is the central issue of the second proposition, formulated in Chapter 1. Private-sector irrigation can be characterized as development from below and at the periphery. As the Sertão is located relatively far from the urban-industrial centres of the Northeast and Southeast, farmers have generally been left alone to develop the type of irrigation system which is best adapted to local conditions. Most are local people and the penetration of urban-industrial interests has been limited to a few very large land-owners. The mentality of local farmers is a practical one of making money with what is within their grasp rather than one where factors of land speculation and development ideology weigh more heavily on farm management.

Most private-sector irrigation farmers, therefore, adopt a flexible strategy of using labour-intensive and low intermediate technology for staple crops while low and high intermediate technology is used for more profitable cash crops. They also use greater amounts of family and sharecropper labour rather than waged labour. This strategy permits them to reduce costs and market risk to the point where considerable profits can be made both in staple and cash cropping. Such a system diffuses more readily than that of the public sector and this is reflected by the fact that the vast majority of irrigation farmers and irrigated land are found in the private sector. These methods are within the reach of most farmers and the gap between dry farming and simpler forms of private-sector irrigation is not so great as to limit the activity to a wealthy minority of farmers. Once adopted, methods evolve relatively fast as farmers discover those which are best adapted to local and market conditions and as they gradually accumulate capital for further intensification.

Large-scale, capital-intensive irrigation is used in the public sector because government planners advocate a top-down and centre-periphery model of accelerated development. Rural change is envisaged as a great leap forward into modern farming as practised in the industrialized world. Planners and administrators make all the crucial decisions and the role of farmers is reduced to merely providing labour. Understandably project farmers are not motivated under such a system. A more serious problem is the fact that they have no input into the decision-making process. The strongly hierarchical and centralized chain of command in the public sector does not allow for feedback from those who till the land and actually see how the crops fare. The mentality prevalent in the irrigation agencies is that this is not needed because the technology already has been proven elsewhere in the world. Project farmers need only be indoctrinated in its proper use. When something goes wrong it is the fault of ignorant project farmers rather than any defect in design.

Public-sector and private-sector irrigation thus represent two opposed models of farm organization. Government projects utilize a variant of the State farm model. While public-sector irrigation of the Sertão does not fully achieve a collective status, it does come close in a number of aspects, though a crucial difference is the fact that project farmers receive income in the form of profits instead of a government salary. However, project farmers do not think of their income as profits but rather as payment from the government which is indeed probably closer to the truth. Public-sector irrigation of the Sertão, therefore, shares with collective farms, the major drawback of low motivation and this is a serious problem when peasant farmers are involved.

Motivation is not a problem in private-sector irrigation. Indeed, it is the basis of a system which permits both farmers and sharecroppers to accumulate capital and so allows for considerable upward social mobility. In sum, the position adopted here is similar to that of Symons (1972) and Schumacher (1973). Agriculture, and especially peasant farming, is a wholly different livelihood from that of manufacturing. If farmers are to work properly they must have direct access to the means of production and this is as much a philosophical question of ties to the land as it is an economic one of distribution of resources and income.

Hall (1978) proposes the direct opposite and his various suggestions for reforming public-sector irrigation would result in the further collectivization and spatial expansion of large-scale irrigation in the Sertão. This would merely accentuate basic flaws in the programme and impose on yet more farmers a system which is simply not adapted to the environmental and socio-economic conditions of the zone.

Flexible production strategy is the key to the third proposition of Chapter 1, i.e. why more desirable social change occurs in private-sector irrigation than in the public sector. Labour-saving devices are used sparingly in the private sector even though labour is relatively scarce. This occurs because, for many farm tasks, labour is still much cheaper to use than machinery. More jobs are created and trends in population growth and migration reflect this. More local people stay and immigrants are drawn to work in private-sector irrigation. Fewer jobs are created in the public sector and indeed rural exodus and unemployment rise sharply when projects are established in densely populated areas of the Sertão. In fact, it may be asked whether the government programme is really aimed at providing farm jobs in the interior because most of the budget goes to administrative positions in the large cities.

Greater social mobility is another consequence of the type of production schemes utilized in private-sector irrigation. More land-owners are able to adopt irrigation and a substantial number of workers are able to rent and purchase farms which is quite different from trends in the public sector or in most other areas of capitalized agriculture of the Northeast and of Brazil. Social disparity between classes of farmers may have increased in both private-sector and public-sector irrigation of the Sertão but this occurs in a more polarized way on the projects. In addition, a good deal of the social disparity in the private sector is caused by external factors, such as the discriminatory nature of farm credit and extension policy. Even so, it must be pointed that inequality is inherent to capitalized agriculture, though the role of government should be to contain this natural tendency and not to encourage it.

In sum, not all is well in the private sector nor is everything bad in the public sector. Indeed, the intentions behind the government programme are good but the means of establishing projects and the course of Brazilian development has sidetracked the programme from the very beginning. Government intervention is not dismissed outright, but rather how it occurs in the case in study. Hence, what follows are suggestions as to what the government could do to strengthen the positive aspects of rural transformation in Sertanejo irrigation.

Within the present Brazilian political and financial context, the role of government should be indirect rather than direct. Instead of trying to dictate which sort of farm system is best or merely helping rich farmers in favourable areas, the government should concentrate on improving rural infrastructure thoughout the whole Sertão. This is necessary for the overall success of all types of farming in the zone. Secondly, the whole urban-industrial bias of economic policy should be changed so that all crops can be planted profitably, which would allow rural incomes to rise throughout the zone and so encouraged people to stay in the Sertão. Direct intervention should be limited to intervening in marketing networks and to redistributing land in places where ownership is overly concentrated. As things are, the combination of environmental problems, underdevelopment and most government policy provoke rural exodus nearly everywhere in the Sertão.

Basic infrastructure of roads, electricity, appropriate-sized reservoirs, drainage systems and other public works need to be established and improved throughout the Sertão. During the last two decades government services have increased substantially but urban zones have benefited most and rural zones hardly at all. Roads connect cities and towns not farming zones to consumer markets. Few rural areas have electricity and when they do, pricing policies, which make farmers pay more than urban consumers, limit its use. Huge reservoirs only serve a minority of project farmers, if anyone at all. Drainage systems hardly exist and those that do are poorly maintained. Most government services in general are centralized in county seats and regional centres and even these are overly dependent on decisions made at the state capital level or higher.

As farm population is concentrated along river courses, providing public services to the rural zone is not as difficult as one might imagine. An integrated river valley system approach could be adopted. Roads, electricity, a series of small dams and a drainage system could be constructed through river basins. While it may be more difficult to build roads and install electricity along water courses than it is in flatter interfluvial areas, more people are served. To date, the feeble attempts at integrated river valley development made by the federal government and regional planning agencies have merely resulted in the construction of hydro-electric dams to provide electricity for the large cities and a few irrigation projects whose produce also goes mainly to the urban market. Furthermore, these public works have been established on merely one or another of the best river valleys of the Sertão. This is not unbalanced development; it is unjust development.

In the last five years, the state governments of Pernambuco and Ceará have been experimenting with a type of programme similar to that suggested here. The Asa Branca project in Pernambuco was being implemented when the researcher was in the field during 1981. Roads are being asphalted, rural electricity is being installed and a series of small flow-over dams are being built along the main rivers of the Sertão in the state. However, instead of making use of local resources for dam construction more expensive materials have been shipped in from the coast. Dams built by local farmers using local materials better withstand flash floods and are nearly ten times cheaper. In addition, as Albuquerque (1981) shows to have occurred historically with public works projects in the Northeast, there are recent reports of land speculators resorting to violence in their attempts to buy out local farmers along the Moxotó River.

Therefore, if such a programme is to be successfully implemented on a wider scale in the zone and is to benefit Sertanejo farmers, measures will have to be taken which encourage the use of local resources and at the same time discourage speculation by city investors. Furthermore, such a programme has to be accompanied by a general reorientation of development priorities in Brazil as a whole. This is necessary not only for resolving the problems of the Northeast but for reducing social disparity and conflict in zones of capitalized agriculture and on the frontier as well. The problems of the Sertão are thus seen to be of national scope and not merely that of drought and underdevelopment in the Northeast.

NOTES

Chapter 1

1. The counties surveyed were: Icó, Iguatu, Jaguaribe, Mombaça, Quixadá, São João do Jaguaribe, and Várzea Alegre in Ceará State; Patos, Serra Branca and Patos in Paraíba State; Alfogados da Ingazeira, Arcoverde, Exu, Floresta, Ouricuri and São Jose do Belmonte in Pernambuco State; and Euclides da Cunha in Bahia State.

Chapter 2

1. Geertz based his views on research undertaken in Indonesia before the advent of the Green Revolution. Since then change has occurred so that Krinks (1978) feels that the term 'involution' no longer applies.

Chapter 3

1. While the latter aim was shown to be correct in the long run the direct opposite occurred with the first aim. The roads allowed the penetration of Southeastern manufactured goods which substituted those of Northeastern manufacture and those made by craftsmen of the interior. This, in turn, caused widespread unemployment and underemployment throughout the region (Hoefle, 1983; Oliveira, 1978).

2. The estimates of Alves and Lisboa for the pre-1913 period (cited in Souza, 1979).

Chapter 4.

1. Such terms as extensive and intensive farming methods are often used rather loosely. Ranching systems of the Sertão are classified according to a typology of Brazilian stock-raising systems which first appeared in Bicalho (1980). Extensive, semi-extensive, semi-intensive and intensive systems are distinguished according to such criteria as breed improvement, reproduction methods, pasture management, intensity in pasture production, use of animal feeds and animal health care.

2. For interviewed farmers of the study area, property size is defined by the amount of bottomland, overall land and the number of cattle owned. A minifundia farmer owns less than 5 hectares of bottomland, less than a total of 50 hectares and has few if any cattle. A small farmer owns 6-10 hectares of bottomland, a total of 50-100 hectares and has a herd of less than 20 cattle in non-

drought years. A medium farmer owns from 10 to 49 hectares of bottomland, a total of 100 to 500 hectares and normally has a herd of from 20-100 cattle. A large property owner has a farm with more than 50 hectares of bottomland, more than 500 hectares in total size and possesses a herd of more than 100 cattle.

Chapter 6.

1. The distribution of the sample data does not permit the calucation of correlation.

2. Soil samples were left in Brazil for analysis of texture. However, only a part were actually analysed so that the data available for soil texture is limited for some places.

3. Correlation was not calculated because of the small sample size on the tributaries.

Chapter 7.

1. A correlation between access to bank loans and technology level is not provided because it was not possible to obtain more detailed information on frequency of bank loans.

Chapter 8.

1. While the average area of rain-fed cotton in the North is large it should be remembered that the crop is planted in less productive lands there.

APPENDIX 1. FIELD RESEARCH QUESTIONNAIRES

a) Irrigation Farmer Questionnaire

QUESTIONÁRIO DE IRRIGAÇÃO - data ________

Proprietário/rendeiro ____________________ município ____________
Fazenda ____________________ localização ____________ Km da sede.

1. Tamanho da propriedade

- área - frente ________ fundos ________ total ________ ha
  - área de baixio ________ ha área de vazante ________ ha
- área arrendada de outros ________ ha localização ________
- área arrendada para outros ________ ha
- área irrigada - frente ________ fundos ________ total ________ ha
- área máxima que pode irrigar ____________ Por que não mais? ____________
- pretende irrigar até ____________ Por que? ____________
- área não irrigada ________ ha Por que? ____________

2. Cultivos

- cultivos irrigados ________________________
  ____
- cultivos anteriores à irrigação - no alto ____________
  ____________ na vazante ____________
- cultivos atuais não irrigados no alto ____________
  ____________ na vazante ____________

3. Adoção de irrigação

- início irrigação 19___ local ____________
- propriedade própria/de terceiros? ____________
- área inicial irrigada ____________ cultivos ____________
- por que resolveu irrigar? ____________
- como aprendeu? ____________
- nesta propriedade começou a irrigação em 19___.
- área ____ ha cultivos ____________
- área atual irrigada ____ ha cultivos atuais ____________
  ____

4. Fonte de água

- rio/nome ________________________
- açude ____________ outro ____________
- meses com disponibilidade de água ____________

5. Captação de água

- cifão 19___ a 19___
- roda d'água 19___ a 19___
- motor diesel 1) 19___ a 19___ (____ hp)
  2) 19___ a 19___ (____ hp)

3) 19___ a 19___ (____ hp)
4) 19___ a 19___ (____ hp)

- eletrobomba 1) 19___ a 19___ (____ hp)
  2) 19___ a 19___ (____ hp)
  3) 19___ a 19___ (____ hp)
- transformador próprio - sim/não - 19____
- aluga água - sim/não. De quem? ____________________________
- pagamento dinheiro/produção. Quanto? ____________________________
- por que mudou? ____________________________

6. Método de irrigação

- uso de quadros, quadros com bancadas, sulcos, outro ____________
- canal principal de terra, alvenaria ________ m, cimento de forma ________ m, canos__________ m.
- irrigação - cifão, aspersor, manual ____________________

7. Preparo da terra

- manual, cultivador, trator, ______________
- trator desde 19___ todo ano? ________ todas as safras? __________
- trator próprio desde 19___ ou alugado - aluga individualmente/junto com parentes e vizinhos - de quem?______________________
  Cr$__________/hora.
- aluga seu trator a terceiros? Cr$ ________/hora.

8. Pousio e rotação de cultivos

- descansa a terra sim/não - por que?____________________
  como?____________________________
  sempre foi assim? ____________________
- rotação de cultivos - sim/não - por que? ________________
  como?____________________________
  sempre foi assim? ____________________
- áreas com problemas de produtividade? ________________
  desde quando? 19___ - por que? ________________
  providências ____________________
- áreas com problemas de sal? ______________ desde quando? 19___
  por que? ____________________________
  providências ____________________

9. Uso de defensivos

- havendo problemas de doença, praga ou de tempo, qual a causa? (mau olhado, Deus, falta de venenos, falta de dinheiro para venenos, outros)____________________
- quem fez/quem é o culpado?____________________
- como prevenir - chifre, garrafa, rezadora, remédios ____________

10. Assistência técnica

- EMATER (frequência) ____________________
- extensionista do projeto (frequência)________________
- outros ____________________________
- recenseamento/anos ____________________

11. Especificações técnicas por cultivos - ___ safra de 19___ (e data que começou usar)

	semente comprada	quadro	quadro com bancada	sulco	molhações (p/sem.)	adubo animal	adubo químico	inseti-cida	fungi-cida	herbi-cida
algodão										
cebola										
melancia										
melão										
tomate										
arroz										
feijão										
mandioca										
milho										
cana										
capim										
fruteiras										

12. Produção e comercialização - Ano 19___

cultivo	Plantio						Produção					Comercialização		
	mês	k	mês	k	perdi-dido	passado (datas)	mês	k	mês	k	con-sumo	Cr$ (k)	local de venda	comprador
algodão														
cebola														
melancia														
melão														
tomate														
arroz														
feijão														
mandioca														
milho														
cana														
capim														
fruteiras														

13. Trabalhadores/administrador

- administrador/encarregado - sim/não - Cr$________/mes,
  participação na produção ____%, roça sem meia ____ha,
  outras vantagens ______________________________
  origem ______________________ anos na propriedade __________
  anos como administrador_____ encargos ______________

14. Trabalhadores meeiros

- no. meeiros com feira - 19__ la safra _____ 2a safra _____
  19__ la safra _____ 2a safra _____
- no. meeiros sem feira - 19__ la safra _____ 2a safra _____
  19__ la safra _____ 2a safra _____
- fornecimento de material ______________________________
  ____
- divisão da produção ______________________________
  ____

15. Trabalhadores/diaristas

- para que cultivos precisa de diaristas e para que tipo de trabalho?
  - preparar quadros/cultivos ______________________
  - plantar/cultivos ______________________
  - mudar/cultivos ______________________
  - limpar/cultivos ______________________
  - colher/cultivos ______________________
  - descascar, ensacar, trancar/cultivos ______________
- pagamento 19__ homem Cr$_____ mulher Cr$_____ menino Cr$_____
  19__ homem Cr$_____ mulher Cr$_____ menino Cr$_____
- local residência durante os dias de trabalho ______________
- origem/residência ______________________
- transporte ______________________

16. Atividades fora da irrigação/agricultura

- agricultura de sequeiro - area_____ ha - cultivos ____________
  ____
- tem aumentado/diminuido ____ por que? ________________

17. Atividades fora da irrigação/criação de animais

Animais	Proprietário				Empregados	
	nº cabeças		raça		nº cabeças	
	atual	passado	atual	passado	atual	passado
bovinos						
cavalos & jegues						
porcos						
caprinos & ovinos						
aves						

Por que tem mais/menos agora? ______________________________

____

18. Empréstimos

- empréstimos bancários - anos ______________ finalidade ________

  ____

  valor ______________________________
- empréstimos de particular ______________________________

  ____

19. Condições fundiárias

- Propriedade é de ______________________________
- aquisição por herança/compra - 19___ por Cr$_________
- expansão (datas) área/valor/objetivo ______________

  ____
- divisão (datas/área/valor/objetivo) ______________

  ____
- benfeitorias encontradas (casas, açudes, etc.) ______________

  ____
- benfeitorias realizadas ______________________________

  ____
- área da propriedade com parentes ______________________________

  ____
- antigo proprietário residia na propriedade? _____ Onde? ________

  ______________ - atualmente ______________________________

20. Esquema da propriedade - Localização na propriedade de: cultivos, pastos, benfeitorias, terras arrendadas, terras em parceria, terras com moradores, tipos de solo (barro, arenoso, rochoso, inaprovetável, salgado, etc., rios, açudes, baixios, altos).

21. Atividades das propriedades vizinhas - tem irrigação, agricultura de sequeiro, pecuafia, abandonadas, etc.

b) Dry Farming Questionnaire

QUESTIONÁRIO DE FAZENDA - data __________

Proprietário/rendeiro______________________ município __________
Fazenda __________________________ localização __________Km da sede

1. Tamanho da propriedade

- área - frente __________ fundos __________ total ________ ha
  - área de baixio __________ ha, área de vazante __________ ha
  - área arrendada de outros ______ ha, localização __________
  - área arendada para outros ______ ha

2. Fonte de água

- rio_ ____________________ com poço natural/escavado
  - água boa/salgada __________ varia no ano __________
- açudes_____ parede, profundidade, fundos __________
  - num ano chuvoso, em que mês a água fica salgada demais? ________
    seca no mês ________
  - num ano com pouca chuva, fica salgada demais em ________
    seca no mês ________
  - quando salgado, ainda pode ser usada para __________
- tanques _____ 19____ - poços _____ 19____
  - num ano chuvoso, em que mês a água fica salgada demais? ________
    seca no mês ________
  - num ano com pouca chuva, fica salgada demais em ________
    seca no mês ________
  - quando salgado, ainda pode ser usada para __________
- cacimbas_____ seca/salga em __________
- reservatórios são cercados/abertos __________

3. Criação de animais

Animais	Proprietário				Empregados	
	nº cabeças		raça		nº cabeças	
	atual	passado	atual	passado	atual	passado
bovinos						
cavalos & jegues						
porcos						
caprinos & ovinos						
aves						

Por que tem mais/menos agora? __________

4. Composição do rebanho

- GADO - touros _____ raça ________________ passado ________________
  bezerros m____ f____, garrotes m____ f____, novilhotes m____ f____
  bois de ano____ vacas ____

- BODE - reprodutores ____ raça _______________ passado _____________
  cabritos m____ f____, marrãos m____ f _____, cabras____

- OVELHA - reprodutores __________ raça ________ passado ____________
  borregos m____ f____, marrãos m____ f____, ovelhas____

5. Forma de criação

- GADO à solta, à solta inverno/preso verão,
  à solta na propriedade cercada/preso verão

- BODE à solta, à solta inverno/preso verão,
  à solta na propriedade cercada/preso verão

- OVELHA à solta, à solta inverno/preso verão,
  à solta na propriedade cercada/preso verão

- PORCO - solto; chiqueiro

- GALINHA - solta; galinheiro

6. Cercados

- propriedade toda cercada/parte ______ ha
- pastos cercados de vara/madeira _______ha, divisões _______________
- pastos cercados de arame _____ ha, fios _______ divisões __________

7. Transferências de animais

- transfere animais para outra propriedade/areas internas na
  na própria propriedade ______ época/mês__________, todo ano? ______
  em que anos? _______________ de que mês a que mês? _________________
  localização e distância _______________ propriedade de ____________
  ________________ forma de pagamento ______________________________
- recebe animais de outros? ____ de quem? ___________________________
  ______________________ forma de pagamento _________________________
- como era no passado? ____

8. Perda de animais e tratamento fito-sanitário

doença	197_	7_	7_	ano normal	providências (frequência)	desde quando?	por que começou?
aftosa							
raiva							
carbúnculo							
bicheira							
mau olhado							
verme							
de seca							
de cobra							
roubo							
BODE/OVELHA							
verme							
caroço							
bicheira							
raiva							
de seca							
roubo							

- O roubo é pior hoje em dia? _____ Que faz quando descobre alugem roubando? ______________________________ Que fazia? _______________

9. Pastagens e forragens

capim/ forragem	pés/ area	teve mais	ano começou	alto/ baixio	para que animais?	época	quando acaba? seca	chuvas
c. nativo								
c.elefante								
c. planta								
c. ______								
c. ______								
palma								
algoroba								
mandacuru								
x.-xique								
restolho								

10. Forragem comprada

tipo	Quantidade 197_	7_	ano normal	passado	para que animais?	época	onde compra?
torta							
farelo							
milho							
palma							
capim							
resolho							

- Possui uma forrageira? ______ Desde 19___.

11. Finalidade do rebanho

- GADO para corte, leite, queijo, cria, recria, reprodutores
  Como era há 20 anos atrás? ______________________________

- BODE/OVELHA para corte, leite, queijo, cria, recria, reprodutores
  Como era há 20 anos atrás? ______________________________

12. Venda de animais

tipo	idade	peso	quanto tempo fica p/recria	época da venda	transporte		local da venda	
					atual	passado	atual	passado
gado								
bode/ ovelha								
porco								
jegue								
aves								

13. Produção de animais

tipo	197_		197_		1975/76		1974		1960s	
	venda	cons	venda	cons	venda	cons	venda	cons	venda	cons
gado										
bode/ ovelha										
porco										
jegue										
aves										

14. Comercialização - Destino final do

- Gado ______________________ passado/data ________________________
- Bode/Ovelha ________________ passado/data ________________________
- Porco ______________________ passado/data ________________________

15. Valor da produção/cabeça

- Gado Cr$_______ /19____; Cr$ _________ 19____
- Bode/Ovelha Cr$ _________ /19____; Cr$ _________ 19____
  pele de bode/ovelha Cr$ _________ /19____; Cr$ _________ 19____
- PORCO Cr$ _________ 19____; Cr$ _________ 19____

16. Produção de leite e derivados

- Leite ______ l/dia ______ l/consumo ______ l/venda.
  - local de venda ________________________ Cr$ _______ /l.
  - variaçõ da produção no ano ____________________________________

- Queijo ______ k/semana ______ k/consumo ______ k/venda
  - local de venda __________________________ Cr$ _______ /k.
  - variaçõ da produção no ano ______________________________________
- Manteiga ______ k/semana______ k/consumo ______ k/venda
  - local de venda __________________________ Cr$ _______ /k.
  - variação da produção no ano ______________________________________

17. Trabalhadores/vaqueiros

- vaqueiros ______ atualmente tem mais ou menos? __________________
  - por que variou? ____
  - tira sorte, 1 em _____ com bezerro (m,f), cabrito (m,f), borrego (m,f).
  - recebe Cr$ _______ /mês, direito à leite ____ l/dia, roça ____ ha.
  - direitos, obrigações e atividades ______________________________
  ____
  - pode criar animais? ____
  - origem ____
  - como se compara com o vaqueiro do passado (data)? ______________
  ____

- ajudantes de vaqueiro ______ atualmente tem mais ou menos? ________
  - por que variou? ____
  - salário Cr$ _______ /mes. vantagens ____________________________
  - atividades ____
  - origem ____

18. Agricultura

- cultivos de alto ____
- cultivos de baixio ____

19. Preparo da terra

- manual, cultivador, trator, _______________
- trator desde 19___ todo ano? _________ todas as safras? __________
- trator próprio desde 19___ ou alugado - individualmente/junto com parentes e vizinhos - de quem? _________________ - Cr$ ______ /hora.
- aluga para terceiros _____ Cr$ ______ /hora.

20. Pousio e rotação de cultivos

- descansa a terra sim/não - por que?______________________________
  como?____
  sempre foi assim? ____
- rotação de cultivos - sim/não - por que? _________________________
  como?____
  sempre foi assim? ____
- áreas com problemas de produtividade? ___________________________
  desde quando? 19___ - por que? __________________________________
  providências ____

- áreas com problemas de sal? ____________________________ desde 19___
  por que? ____
  providências ____

21. Uso de defensivos

- havendo problemas de doença, praga ou de tempo, qual a causa? (mau olhado, Deus, falta de venenos, falta de dinheiro para venenos, outros) ____________________

- quem fez/quem é o culpado? ____________________

- como prevenir - chifre, garrafa, rezadora, remédios ____________

22. Especificações técnicas por cultivos - ___ safra de 19___
(estipular data em que começou a usar)

cultivo	semente comprada	adubo animal	adubo químico	inseticida	fungicida	herbicida
algodão						
arroz						
feijão						
melancia						
milho						
fruteiras						

23. Produção e comercialização - Ano 19___

cultivo	Plantio				Produção			Comercialização		
	mês	k	perdido	passado (datas)	mês	k	consumo	Cr$ (k)	local de venda	comprador
algodão										
arroz										
feijão										
melancia										
milho										
fruteiras										

24. Assistência técnica

- EMATER (frequência) ______________________
- extensionista do projeto, DPV/A (frequência) ______________
- outros ______________________________
- recenseamento/anos ______________________

25. Trabalhadores/administrador

- tem administrador/encarregado - sim/não - Cr$________/mes,
- participação na produção _____%, roça sem meia _____ha,
- outras vantagens ______________________
- origem ____________________ anos na propriedade __________
- anos como administrador_____ encargos ______________

26. Trabalhadores/moradores

- no. moradores ______ 19___; ______ 19___
- passado/data ____________ por que mudou? ____________
- obrigações ______________________________
- o que podem ou não plantar? ______________________
- plantam com meia/sem meia ______________________
- podem criar animais? Quais? ______________________
- por que não? ______________________________
- qual a vantagem em ter moradores? ______________
____
- é diferente hoje do passado? ______________________
____

27. Trabalhadores meeiros

- no. meeiros ______ 19___; ______ 19___
- passado/data ____________ por que mudou? ____________
- cultivos com meeiros ______________________
- decisão do plantio por parte do meeiro/proprietário ________
____
- fornecimento de material ______________________
____
- divisão da produção ______________________
____
- plantam sem meia para consumo/venda ______________
____
- podem criar animais? ______________________
- por que não? ______________________________
- origem ______________________________

28. Trabalhadores/diaristas

- para que cultivos precisa de diaristas e para que tipo de trabalho?
  - brocar/cultivos ______
  - plantar/cultivos ______
  - mudar/cultivos ______
  - limpar/cultivos ______
  - colher/cultivos ______
  - descascar, ensacar, outro ______
- pagamento 19___ homem Cr$______ mulher Cr$______ menino Cr$______
  19___ homem Cr$______ mulher Cr$______ menino Cr$______
- residência durante trabalho ______
- origem/residência ______
- transporte ______

29. Trabalho familiar

- membros da família que trabalham na agricultura ______
  ______ na pecuária ______
- forma de remuneração ______
- área explorada só com família ______
- troca dias com parentes/vizinhos ______

30. Empréstimos

- empréstimos bancários - anos ______ finalidade ______
  ______
  valor ______
- empréstimos de particular ______
  ______

31. Condições fundiárias

- Propriedade é de ______
- aquisição por herança/compra - 19___ por Cr$______
- expansão (datas) área/valor/objetivo ______
  ______
- divisão (datas/área/valor/objetivo) ______
  ______
- benfeitorias encontradas (casas, açudes, etc.) ______
  ______
- benfeitorias realizadas ______
  ______
- área da propriedade com parentes ______
  ______
- antigo proprietário residia na propriedade? ______ Onde? ______
  ______ - atualmente ______

32. Esquema da propriedade - Localização na propriedade de: cultivos, pastos, benfeitorias, terras arrendadas, terras em parceria, terras com moradores, tipos de solo (barro, arenoso, rochoso, inaproveitável, salgado, etc.), rios, açudes, baixios, altos, cercas.

33. Atividades das propriedades vizinhas - tem irrigação, agricultura de sequeiro, pecuafia, são abandonadas.

c) Worker Questionnaire

QUESTIONÁRIO DE TRABALHADOR - data ______

Meeiro/vaqueiro/morador/diarista/administrador/ ____________________
Município ____________________
Fazenda ______________ localização ______________ km da sede

1. Anos nesta propriedade de 19___ a 19___

outras fazendas	município	atividade	data
			19___ a 19___
			19___ a 19___
			19___ a 19___
			19___ a 19___
			19___ a 19___
			19___ a 19___

Em que cidade ja morou?	atividade	data
		19___ a 19___
		19___ a 19___
		19___ a 19___
		19___ a 19___
		19___ a 19___

por que saiu de cada lugar? ____________________
____
____

2. Já teve sua própria roça? ________ 19___ a 19___
- localidade ____________________
- plantava ____________________
- criava ____________________
- tinha escritura __________ era posse __________ arrendava __________ outro ____________________

3. Em época de muito serviço, quantos dias trabalhava para o patrão? ________ e quando tem pouco serviço? ________
- quanto recebe? Cr$________
- tem obrigação de dias? quantos? ____________________
- atividades ____________________
- seus filhos tambem trabalham? ________ Quantos dias? ________ recebem Cr$ ________/________
- no ano passado teve trabalho na roça o ano inteiro? ________
- outras atividades (local/duração) ____________________
____

4. MEEIRO/MORADOR

- quanto ganhou no ano passado depois das contas? 1a.safra Cr$ ______ 2a.safra Cr$ ______ 3a.safra Cr$ ______ 19___
- outros anos ____________________
- fornecimento, empréstimos, divisão e venda da produção ________
____
____
____

5. VAQUEIRO

- Salário Cr$ ______ /________ outras vantagens (roça/leite, etc.)
____
- sorte 1 em ____ gado, bode, ovelha (m, f).
- sempre foi com estes animais e nesta proporção? ______________
- quantos animais recebeu no ano passado?
  bezerros _____ - cabritos _____ - borregos _____
- recebeu mais/menos nos outros anos? ______________________
- por que variou? ______________________________________
- o que faz com os animais tirados na sorte? _______________
  é obrigado a vender? ______ pode mantê-los na propriedade? _______
- o que faz com seus animais durante uma seca forte? __________
____
- é possível para um vaqueiro passar a ser fazendeiro ou comprar um sítio? ______________________________________
  por que? ____
- conhece algum vaqueiro que se tornou proprietário? __________
  quando? ____

6. Animais - fica junto os do patrão, na propriedade? _____

- criação ___ (meia), teve mais/menos/porque? ______________
- porco ___ (meia), teve mais/menos/porque? ______________
- aves ___ (meia), teve mais/menos/porque? ______________
- gado ___ (meia), teve mais/menos/porque? ______________
____

7. Já perdeu algum de seus animais? _____

- quantos em que anos ____________________________________
  _______________________ de que? _________________________
- o que fez? ____
- mal olhado/rezar/rasto __________________________________
- vacina (quais/contra o que/frequência) ____________________
  ____
  desde quando vacina (cada doença)? _______________________
  por que começou? ____
  vacina junto com os da fazenda? __________________________

8. Para que são seus animais?

- vender (no. cabeças/ano) ________________________________
- consumo (no. cabeças/ano) _______________________________
- leite (litros/dia/meses) ________________________________
- ovos (no./sem.) ____ vende no.____ onde? ________ p/quem? ________
- vende leite ____ (1/sem.) ___/___ onde? ________ p/quem? ________

9. Quando mata um animal é só para a família? ____

- no ano passado deu uma parte para parentes (tipo ______________), vizinhos, amigos?
  gado ___k, criação ___k, porco ___k, galinha ___k - espera retribuição (de quais/quando)? ____________________________

- vendeu uma parte? ____ para quem? ____________________
  gado ___k, criação ___k, porco ___k, galinha ___k
- como era? ____________________

____

10. Na sua roça, quem decide o que vai ser plantado? ____________

- a área e local de plantio? ____________________
- pode plantar o que quiser? ____________________
  por que não? ____________________
  o que preferiria plantar e por que? ____________________

  ____
- a roça fica no baixio/alto - tem _____ha/tarefas
- que tipo de solo tem? ____________________
- descansa a terra? ____________________
  sempre fez assim? ____________________

11. Técnica Agrícola

- quando tem problema de doença, praga ou do tempo qual a causa (olhado, Deus, falta dinheiro p/venenos, etc.)? ____________

  ____
  como prevenir contra isso (chifre, garrafa, rezadora)? ________

  ____
- usa estrume? _____ em que cultivos? ____________________
  onde arranja (quem/paga/distância/transporte)? ____________
  ____________________ quando começou/porque nestes cultivos? ____________________
- que outros venenos (em que cultivos)? ____________________

  ____
  onde arranja? ____________________
  quando começou/porque nestes cultivos? ____________________

  ____
- usa trator ou cultivador? _____ de quem? ____________ Cr$ _____
  desde quando? 19___ por que começou/não usa? ____________
- assistência de EMATER (frequência) ____________________
  patrão, outros ____________________
- recenseamento (anos) ____________________

12. Produção e comercialização - Ano 19___

cultivo	Plantio				Produção			Comercialização		
	mês	k	perdido	passado (datas)	mês	k	consumo	Cr$ (k)	local de venda	comprador
algodão										
arroz										
feijão										
melancia										
milho										
fruteiras										

13. A esposa e filhos ajudam na roça/com a criação?

- quais e o que faz cada um? ___
- outras atividades deles (local/duração) ___

___

- quer mais filhos para ajudá-lo? ___

14. Recebe ajuda de parentes (tipo ___), amigos, vizinhos, conhecidos, estranhos?

- quando/tipo trabalho? ___
- paga ou troca dias de trabalho com eles? ___
- como era? ___
- por que mudou? ___

d) Social Questionnaire

QUESTIONÁRIO SOCIAL - data ______

Proprietário/rendeiro/meeiro/morador/vaqueiro/diarista/administrador
Nome ______________________ Fazenda ______________________

1. Família

pessoa	idade	sexo	local de nascimento	anos de estudo	locais de estudo	residência	atividade
Sr.							
esposa							
filhos							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
outros em casa (sobrinho, afilhado, sogra, empregado, etc.)							

no. filhos falecidos ___ idade ________ causa ______________

2. Residências anteriores (local/data/atividade) ____________________
____
____
____
- por que mudou-se para cá? ______________________________________

3. Experiência agrícola anterior - data/atividade exercida (com pai, própria, morador, vaqueiro, meeiro, diarista, outro) ____________
____
____

4. Outras atividades no presente/passado (data) ____________________
____

5. Já foi para o Sul ou para a Capital? Quando e por que? __________
____

6. Posse de imóveis ____
____

7. Residência

- própria 19 ___, alugada Cr$ _____ /mês, emprestada de __________
- no. comodos ________ paredes de __________ água de ________
- telhado de ________ fogão de __________ energia ________
- chão de ________ banheiro __________ rua calçada ________
(fora, dentro)

8. Objetos domésticos

- rádio ______ desde 19 ____ televisão (cor?) ______ 19___
- vitrola ______ 19 ____ telefone ______ 19___
- gravador ______ 19 ____ máquina de costura ______ 19___
- geladeira ______ 19 ____ empregados domésticos ______ 19___
- outros ____
- carro ______ desde 19____ modelo/ano ____________________
- camionete ______ desde 19____ modelo/ano ____________________
- caminhão ______ desde 19____ modelo/ano ____________________
____
____

9. Assistência social

- hospital/posto/prático/ (local/para que) ______________________
____
- escolas (local/distância/nível) ________________________________
- INPS, FUNRURAL, Sindicato. Desde 19___
por que? ____

10. Residência e atividades

- dos seus pais ____________________
- de seus irmãos ____________________
____
- de suas irmãs ____________________
____
- dos pais de sua esposa ____________________
- dos irmãos de sua esposa ____________________
____
- das irmãs de sua esposa ____________________
____

11. Pais proprietários

- seus pais - sim/não - localização ______________ área _____ ha
- atividades exploradas ____________________
- pais de sua esposa - sim/não - localização ______________
  area _____ ha - atividades exploradas ______________

12. Consumo semanal de comida

- carne	______	k	arroz	______	k
- peixe	______	k	feijão	______	k
- ovos	______		milho	______	k
- leite	______	l	farinha	______	k
- queijo	______	k	manteiga	______	k/l

13. Dias de trabalho no mês

- janeiro	______	maio	______	setembro	______
- fevereiro	______	junho	______	outubro	______
- março	______	julho	______	novembro	______
- abril	______	agosto	______	dezembro	______

atividades na época de mais trabalho ____________________
____
e na época de menos trabalho ____________________
____

14. Renda familiar (todos os membros da família)

	19___	19___
- produção agro-pecuária	Cr$ ______________	Cr$ ______________
- salário Sr. (______/mês)	______________	______________
Sra.(______/mês)	______________	______________
filhos______/mês)	______________	______________
- Outros FUNRURAL	______________	______________
comércio	______________	______________
negócios	______________	______________
aluguéis	______________	______________
______________	______________	______________

15. Em geral a vida e mais fácil, mais difícil ou igual do que há uns quinze anos atrás? Como/por que? ____________________
____

APPENDIX 2. IRRIGATION TECHNOLOGY INDEX

The farms of the study area were classed according to an index of irrigation technology which is based on the general model of irrigation technology presented in Chapter 2. Numerical values were assigned to the different technological characteristics of the model according to the degree of capital intensity. The index merely measures the use of capital in farming and is not meant to convey any connotation as to which method is better than the others.

Each trait received a scaled value ranging from 0, the most labour-intensive case observed, to 100, the most capital-intensive case within the possibilities of the model. The index value for each farm is the average of the individual scores achieved below.

1. Water storage facility (applicable for seasonal rivers only)

none	0
water is not sufficient for the whole year, reservoir empty during dry season	33
water sufficient for one whole year, reservoir dry during droughts	67
perennial, reservoir dry only during prolonged drought	100

2. Water lifting device utilized

natural inundation by river during rainy season	0
manual watering with kerosine tin	13
pump powered by natural forces (wind mill, water wheel, siphon from reservoir)	25
pay for water from neighbour with a pump (not reliable)	38
deisel motor pump	50
electric pump	63
2 deisel or electric pumps	75
3-4 deisel or electric pumps	88
pump network (5 or more pumps)	100

3. Type of irrigation canals

no canals	0
earth canals	33
brick lined canals or plastic tubing	67
molded concrete canals or steel piping	100

4. Control of water volume

no control	0
amount controlled by estimation according to experience	50
mechanical calibration	100

5. Manner of distributing water to crops

natural inundation in depressions	0
controlled natural inundation	17
free flowing distribution	33
breaking secondary or terciary earth canal or retaining wall	50
siphoning water over retaining wall	66
sliced retaining wall network	83
sprinkling or tube subirrigation	100

6. Irrigation methods

no channeling or retaining of water	0
inundation basins	25
inundation basins with raised internal planting areas	50
furrows	75
sprinkers or tube subirrigation	100

7. Drainage control

no means of drainage	0
shallow earth drainage canals	17
shallow gravel or rock lined canals	33
reasonably deep gravel or rock lined canals	50
complete network of deep canals	66
pumping off of excess water	83
use of chemical dissolvents to remove salt	100

8. Mode of land preparation

planting using digging stick	0
turning land with hoe	25
turning land with animal drawn plow	50
turning land with rented tractor	75
turning land with own tractor	100

9. Intensity of land use and system for conserving soil fertility

shifting cultivation with long fallow after 2 to 3 years of use, no fertilizers	0
fallow of 4 years after 2 years of use, no fertilizers	10
fallow of 1-2 years after 1-2 years of use, no fertilizers	20
fallow of 2-3 months after a single harvest, no fertilizers (fertility & productivity decline sharply)	30
permanent fruit tree crop or pasture, no fertilizers (little investment)	40
fallow of 2 years after 2 years of single harvests, fertilizers & indirect manuring through pasturing during fallow	50
permanent fruit tree crop, fertilizers	60
fallow of 2-3 months after a single annual harvest, fertilizers & indirect manuring through pasturing during fallow	70
fallow of one and a half years after 2 to 3 years of multiple harvests per year, fertilizers & indirect manuring through pasturing during fallow, crop rotation	80
fallow of 2-3 months after 2 harvests per year, fertilizers & indirect manuring through pasturing during fallow, crop rotation	90
little fallow between multiple harvests per year, heavy use of fertilizers, crop rotation	100

10. Use of pesticides

no action taken	0
manual methods	50
use of pesticides	100

APPENDIX 3. INDEX OF SOCIAL DISPARITY

The index of social disparity used here was devised together with S.W. Hoefle and first appeared in a preliminary form in Bicalho (1980). The idea for the index was based on a Quality of Life Index used by the Overseas Development Council (1979). The Council's index is a much simpler one, which utilizes only three indicators. In addition, their index is used primarily for comparing the level of development of different countries and regions. The index used in this work is employed to measure class disparity in a specific region and is based on local criteria that the people themselves regard as important for distinguishing social position.

Calculation of the index is made by averaging the scores of the five indicators: housing, household furnishings, level of formal education, mode of transport and diet. Each indicator can have sub-indicators, whose average yields the overall score for the criterion. Indicators and sub-indicators use a scale of 0 - 100, where 0 is the minimal observed condition for the criterion in question and 100 is the maximum condition. The index first used in the Agreste had the additional indicator of health as reflected in infant mortality. However, infant mortality in the Sertão is low by Northeastern standards and access to medical facilities is not yet determined by class situation.

1. Housing

a) Number of residences (of similar quality of construction)

no fixed residence	0
one residence	33
two residences	67
three residences	100

b) Location of residence

no fixed residence	0
on the farm	20
village or hamlet	40
county seat	60
hub city	80
metropolitan area	100

c) Access to house (urban areas only)

trail	0
unpaved street	50
paved street	100

d) House ownership

squatter	0
loaned	33
rented	67
owned	100

e) Lot ownership

squatter	0
loaned	33
rented	67
owned	100

f) House size

no house	0
1 room	7
2 rooms	14
3 rooms	21
4 rooms	28
5 rooms	36
6 rooms	43
7 rooms	50
8 rooms	57
9 rooms	64
10 rooms	71
11 rooms	78
12 rooms	85
13 rooms	92
14 rooms and more	100

g) Type of construction: flooring

beaten earth	0
bare brick	25
cement	50
ceramic tile	75
parqué	100

h) Type of construction: walls

lacking walls	0
thatched palm fronds, plastic sacks and other non-durable material	20
wattle-and-daub	40
wattle-and-daub sealed with cement plaster	60
bare brick	80
plastered brick	100

i) Type of construction: roof

lacking roof	0
palm frond thatched roof	33
tiled roof	67
tiled roof with ceiling	100

j) Water supply

seasonal untreated water	0
perennial untreated water	33
untreated water stored in water tank	67
piped treated water	100

k) Sewage system

none	0
septic tank	33
septic tank with toilet	67
sewage system	100

l) Electricity

none	0
generator electricity	50
main line electricity	100

2. Household furnishings

a) Furniture

none	0
rustic style of local craftsmen	25
modern style of local craftsmen or manufactured	50
old style refined of local craftsmen	75
modern style refined manufactured	100

b) Number of household appliances

none	0
1 appliance	7
2 appliances	14
3 appliances	21
4 appliances	28
5 appliances	36
6 appliances	43
7 appliances	50
8 appliances	57
9 appliances	64
10 appliances	71
11 appliances	78
12 appliances	85
13 appliances	92
14 appliances and more	100

3. Formal Education

a) Level attained by persons having finished school

i) over 40 years of age

illiterate	0
able to sign name	14
incomplete primary school or able to read and write	29
complete primary school	43
incomplete _ginásio_ level of secondary school	57
complete _ginásio_ level of secondary school	72
incomplete _colégio_ level of secondary school	86
complete secondary school or higher(a)	100

(a) Persons over 58 years of age who have finished what was later called _ginásio_ are counted as having finished secondary school because _colégio_ level of secondary school did not exist prior to the 1940s and the _ginásio_ level lasted longer

ii) under 40 years of age

illiterate	0
able to sign name	11
incomplete primary school or able to read and write	22
complete primary school	33
incomplete _ginásio_ level of secondary school	44
complete _ginásio_ level of secondary school	56
incomplete _colégio_ level of secondary school	67
complete secondary school	78
incomplete university	89
complete university or higher	100

b) Variance of age from that which is normal for each grade for children who are still studying (beyond primary school)

not studying (children of primary school age)	0
4 or more years of variance	25
up to 3 years of variance	50
up to 2 years of variance	75
0 - 1 year of variance	100

c) Place of study

did not study	0
all courses done locally	20
courses done in the county seat (when from rural zone)	40
1 course level done elsewhere	60
2 course levels done elsewhere	80
3 or more course levels done elsewhere	100

4. Transport

on foot or mounted	0
bicycle	11
taxi or ferry	22
pickup truck	33
passenger car	44
lorry	56
2 pickup trucks, lorries or passenger cars	67
3 pickup trucks, lorries or passenger cars	78
4 pickup tracks, lorries or passenger cars	89
5 or more pickup trucks, lorries or passenger cars	100

5. Diet

Diet was judged by the amount of meat consumed as this was found to be closely related to social position. The lowest daily per capita amount of meat consumed that was observed, none at all, receives the score of zero and the highest amount, 440 grammes, was scored as 100. All other amounts receive scores proportionately on the scale between these extremes. Calculation of per capita meat consumption took variation according to age and sex into account.

BIBLIOGRAPHY

ADAMS, R.M. 1966. *The Evolution of Urban Society*. Chicago: Aldine.

AGUIAR, R.C. 1981. Alimentos: Um Prato Cheio de Problemas. *Revista Brasileira de Tecnologia* 12(1): 66-70.

AGROVALE. n.d. *Perfil Agro-Industrial: Usina Mandacuru - Juazeiro, Bahia*. Brasília: CODEVASF.

ALBRECHT, H. 1982. Small Farmers and Agricultural Extension in West Germany: Widening Gaps or Solving Problems? In *Progress in Rural Extension and Community Development: Extension and Relative Advantage in Rural Development*, G.E. Jones & M. Rolls (eds.), pp. 155-170. Chichester: John Wiley & Sons.

ALBUQUERQUE, M.M. 1981. *Pequena História da Formação Social Brasileira*. Rio de Janeiro. Edições Graal.

AMIRIM, D.H.K. 1970. Geographic Considerations in Plans for Development. In *Arid Lands in Transition*, H.E. Dregne (ed.), pp. 89-103. Washington, DC: American Association for the Advancement of Science.

ANDRADE, F.A. 1960. *Agropecuária e Desenvolvimento do Nordeste*. Fortaleza: Universidade do Ceará.

ANDRADE, G.O. 1977. *Alguns Aspectos do Quadro Natural do Nordeste*. Recife: SUDENE.

ANDRADE, M.C. 1973. *A Terra e o Homem no Nordeste*. São Paulo: Editora Brasiliense.

-----. 1975. *O Processo de Ocupação do Espaço Regional do Nordeste*. Recife: SUDENE.

ARNON, I. 1981. *Modernization of Agriculture in Developing Countries: Resources, Potentials, and Problems*. Chichester: John Wiley & Sons.

BARROSO, G. 1947. A Origem da Palavra 'Sertão'. *Boletim Geográfico* 5 (52): 401-403.

-----. 1956. *Terra de Sol*. Rio de Janeiro: Livraria São José.

BAYLISS-SMITH, T.P. 1982. *The Ecology of Agricultural Systems*. Cambridge: Cambridge University Press.

BANCO DO NORDESTE DO BRASIL. 1957. *Irrigação na Área Pernambucana do São Francisco*. Fortaleza.

BARAN, P.A. 1968. *The Political Economy of Growth*. New York: Monthly Review Press.

BASTIDE, R. 1973. *Brasil Terra de Contrastes*. São Paulo: Difusão Européia do Livro.

BELSHAW, C.S. 1965. Traditional Exchange and Modern Markets. Englewood Cliffs, NJ: Prentice-Hall.

BERSTEIN, H. 1982. Notes on Capital and Peasantry. In Rural Development: Theories of Peasant Economy and Agrarian Change, J. Harriss (ed.), pp. 160-177. London: Hutchinson University Library.

BICALHO, A.M.S.M. 1980. A Pecuária e as Transformações do Agreste: O Exemplo de Guarabira. Unpublished M.Sc. Thesis, Universidade Federal do Rio de Janeiro.

BICALHO, A.M. & S.W. HOEFLE. 1979. Transformações na Vida Sertaneja: A Irrigação no Rio São Francisco. Revista Pernambucana de Desenvolvimento 6 (1): 75-110.

-----. 1983. Changing Labour Relations in the Brazilian Semi-Arid Zone. Occasional Papers in Geography 16. London: Bedford College.

BIENEFELD, M. 1980. Dependency in the Eighties. Bulletin 12(1): 5-10.

BOSERUP, E. 1965. The Conditions of Agricultural Growth. Chicago: Aldine.

BOWDEN, L.W. 1965. Diffusion of the Decision to Irrigate. Chicago: University of Chicago.

BROOKFIELD, H. 1975. Interdependent Development. London: Methuen.

-----. 1979. Urban Bias, Rural Bias, and the Regional Dimension. In, Toward a New Strategy for Development, K.Q. Hill (ed.), pp. 97-122. New York: Pergamon Press.

BUREAU OF RECLAMATION/SUDENE/SUVALE/CHESF. 1970. Reconhecimento dos Recursos Hidráulicos e de Solos da Bacia do Rio São Francisco. Rio de Janeiro.

BYRES, T.J. 1974. Land Reform, Industrialization and the Marketed Surplus in India: An Essay on the Power of Rural Bias. In Peasants, Landlords and Governments, D. Lehmann (ed.), pp. 221-261. New York: Holmes & Meier.

-----. 1979. Of Neo-Populist Pipe Dreams. Journal of Peasant Studies 6(2): 210-244.

-----. 1983. Historical Perspectives on Sharecropping. Journal of Peasant Studies 10(2/3): 7-40.

CABELLERO, J.M. 1983. Sharecropping as an Efficient System: Further Answers to an Old Puzzle. Journal of Peasant Studies 10(2/3): 107-117.

CANTOR, L.M. 1967. A World Geography of Irrigation. London: Oliver & Boyd.

CARDOSO, F.H. & E. FALETTO. 1979. Dependency and Development in Latin America. Berkeley, CA: University of California Press.

CARVALHO, J.C. 1978. Camponeses no Brasil. Petrópolis: Vozes.

CATELLI, G.P. 1981. Borgo a Mozzano Revisited: A Sociological Evaluation of the Diffusion of Innovations. In Extension Education and Rural Development: International Experience in Communication and Innovation, B.R. Crouch & S. Chamala (eds.), pp. 85-96. Chichester: John Wiley & Sons.

CHAMBERS, R. 1983. Rural Development: Putting the Last First. London: Longman.

CHEUNG, S.S. 1969. The Theory of Share Tenancy. Chicago: University of Chicago Press.

CIDA. 1975. La Mano de Obra Agricolá en el Latifundismo. In La Lucha de Classes en el Campo, E. Feder (ed.), pp. 140-205. Mexico City: Fondo de Cultura Economica.

CLINE, W.R. 1972. Análise de Custo-Benefício de Projetos de Irrigação no Nordeste. Pesquisa e Planejamento Econômico 2(2).

CLOUDSLEY-THOMPSON, J.L. 1970. Animal Utilization. In Arid Lands in Transition, H.E. Dregne (ed.), pp. 57-72. Washington, DC: American Association for the Advancement of Science.

CODEVASF (Companhia do Desenvolvimento do Vale do São Francisco). 1975. Projeto Executivo de Irrigação de Maniçoba e Curaçá. Rio de Janeiro.

-----. 1979a. Pesquisa Agro-Social do Projeto Curaçá. (Mimeo).

-----. 1979b. Pesquisa Agro-Sócio-Econômica da Área do Projeto Maniçoba. (Mimeo).

-----. 1979c. Pesquisa Sócio-Econômica do Projeto de Irrigação de Massangano. (Mimeo).

-----. 1979d. Critério para Cessão de Áreas Irrigadas. Brasília (mimeo).

-----. n.d. 1. Áreas Prioritárias da CODEVASF. Brasília.

-----. n.d. 2. Plano Agrícola do Projeto Bebedouro - 1981. (Mimeo).

-----. n.d. 3. Normas de Colonização. Brasília (mimeo).

-----. n.d. 4. Avaliação da Fertilidade do Solo do Projeto de Irrigação de Bebedouro em Petrolina. (Mimeo).

-----. n.d. 5. Contrato de Arrendamento Rural. Brasília (mimeo).

COELHO, J. 1974. Considerações em Torno do Programa de Agricultura Irrigada na Zona Semi-Árida do Nordeste. Boletim de Agricultura 2(2): 61-80.

----- n.d. Política Agrícola para a Zona Semi-Árida do Nordeste: Necessidade de uma Reorientação. (Mimeo).

COELHO, J. & A. BRASILEIRI. 1977. Crédito Rural no Nordeste e os Serviços Complementares. Recife: SUDENE/EMATERPE.

CORBRIDGE, S. 1982. Urban Bias, Rural Bias, and Industrialization: An Appraisal of the Work of Michael Lipton and Terry Byres. In Rural Development: Theories of Peasant Economy and Agrarian Change, J. Harriss (ed.), pp. 94-116. London: Hutchinson University Library.

CROUCH, B.R. & S. CHAMALA. 1981. Overview. In Extension Education and Rural Development: International Experience in Communication and Innovation, B.R. Crouch & S. Chamala (eds.), pp. xi-xxvi. Chichester: John Wiley & Sons.

CUNHA, E., 1944. Rebellion in the Backlands. Chicago: University of Chicago Press.

CUNLIFFE, R.L. 1975. The Birth of the Drought Industry: Imperial and Provincial Response to the Great Drought in Northeast Brazil 1877-1880. Revista de Ciências Sociais 6(1/2): 65-82.

DJURFELDT, G. 1982. Classical Discussions of Capital and Peasantry: A Critique. In Rural Development: Theories of Peasant Economy and Agrarian Change, J. Harriss (ed.), pp. 139-159. London: Hutchinson University Library.

DNOCS (Departamento de Obras Contra as Secas). 1968. Aproveitamento Hidro-Agrícola do Açude Público Sumé. Recife.

-----. 1970. Projeto Cachoeira II. Recife.

-----. 1971a. Projeto Eng. Arcoverde: Aproveitamento Hidro-Agrícola do Açude Público Eng. Arcoverde. Recife.

-----. 1971b. Estudos Básicos: Custodia, Entremontes e Araras. Recife.

-----. 1976. II Plano Nacional de Desenvolvimento: Programa de Irrigação do Nordeste Semi-Árido. Fortaleza.

-----. 1977. Projeto de Irrigação Saco II. Recife.

-----. 1981. Projeto de Irrigação Baixo Açu - Seleção, Assentamento e Treinamento de Irrigantes. Fortaleza (mimeo).

-----. n.d. Projeto de Irrigação Brumado. Fortaleza.

DNOCS/COBA/ERN. n.d. Projeto de Irrigação do Vale do Rio Moxotó. Rio de Janeiro.

DNOCS/GEOBRAS. 1967. Vale do Pajeú: Recursos em Água e Solo.

DNOCS/NORONHA. n.d. Replanejamento do Sistema de Irrigação do DNOCS. Fortaleza.

DREGNE, H.E. 1970. The Changing Scene. In Arid Lands in Transition. H.E. Dregne (ed.), pp. 7-14. Washington, DC: American Association for the Advancement of Science.

DUNN, P.D. 1978. Appropriate Technology: Technology with a Human Face. London: MacMillan.

DUQUE, J.G. 1973. O Nordeste e as Lavouras Xerófilas. Fortaleza: Banco do Nordeste do Brasil.

-----. 1980. Solo e Água no Polígono das Secas. Fortaleza: DNOCS.

EDEN, M.J. 1974. Irrigation Systems and the Development of Peasant Agriculture in Venezuela. Journal of Economic and Social Geography 16(1): 48-54.

EDEN, M.J. & PORTER, V. 1979. Land Colonisation and Agricultural Development in Lowland Venezuela. London: Bedford College.

EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária). 1972/73. Levantamento Exploratório - Reconhecimento dos Solos de Pernambuco. Recife.

-----. 1974-1981. Sistemas de Produção no. 5, 63, 68, 94, 101, 255, 256, 290 & 291. Brasília.

-----. 1977/79. Levantamento Exploratório - Reconhecimento de Solos da Margem Direita do Rio São Francisco Estado da Bahia. Recife.

EMATERPE (Empresa de Assistência Técnica Rural de Pernambuco). 1975. Dados Preliminares de Produção de Citrus Irrigado por Gotejo e Inundação. Recife.

ENTE PER LO SVILUPPO DELL'IRRIGAZIONE E LA TRANSPORTAZIONE FONDIARIA IN PUGLIA E LUCANIA. 1957. L'activite de L'office pour le Development de L'irrigation et la Transformation Agraire dan la Pouille et la Lucanie. Bari.

EPSTEIN, S. 1971. Economic Development and Social Change in South India. In, Economic Development and Social Change, G. Dalton (ed.), pp. 460-491. Garden City, NY: The Natural History Press.

EVANS, D.D. & L.N. ADLER (eds.). 1979. Appropriate Technology for Development: A Discussion and Case Studies. Boulder, CO: Westview Press.

FACÓ, R. 1976. Cangaceiros e Fanáticos. Rio de Janeiro: Editora Civilização Brasileira.

FALCÃO, M.L. 1980. Estudo Hidroquímico da Bacia Hidrográfica do Riacho do Navio (PE). Unpublished M.Sc. Thesis, Universidade Federal do Pernambuco.

FEDER, E. 1971. The Rape of the Peasantry. New York: Anchor Books.

FERRAZ, M.L. 1975. Quinta Agência Regional: Um Marco na História da Irrigação. Juazeiro: CODEVASF.

FIGUEROA, M. 1977. O Problema Agrário no Nordeste do Brasil. São Paulo: HUCITEC/SUDENE.

FIGUEIREDO FILHO, J. 1958. Engenhos de Rapadura do Cariri. Rio de Janeiro: Serviço de Informação Agrícola.

FLYNN, P. 1978. Brazil: A Political Analysis. London: Ernest Benn.

FORMAN, S. 1975. The Brazilian Peasantry. New York: Columbia University.

FORMAN, S. & J.F. RIEGELHAUPT. 1970. Market Place and Marketing System: Toward a Theory of Peasant Economic Integration. Comparative Studies in Society and History 12(2): 188-212.

FOSTER, G. 1973. Traditional Societies and Technological Change. New York: Harper & Row.

-----. 1976. Peasant Society and the Image of Limited Good. In, Selected Papers from the American Anthropologist, R.F. Murphy (ed.), pp. 382-404. Washington, DC: AAA.

-----. 1979. Tzintzuntzan: Mexican Peasants in a Changing World. New York: Elsevier.

FOX, R. 1979. Preços Mínimos Guarantidos e o Setor Agrícola no Nordeste do Brasil. Revista Econômica do Nordeste 10(2): 551-604.

FRANK, A.G. 1969. Capitalism and Underdevelopment in Latin America. New York: Monthly Review Press.

-----. 1970. Latin America: Underdevelopment or Revolution. New York: Monthly Review Press.

FUNDAÇÃO IBGE. 1952. Estudos da Zona de Influência da Cachoeira de Paulo Afonso. Rio de Janeiro.

-----. 1955a. Recenseamento Geral do Brasil - 1950: Censo Demográfico. Rio de Janeiro.

-----. 1955b. Recenseamento Geral do Brasil - 1950: Censo Econômico. Rio de Janeiro.

-----. 1962. Recenseamento Geral do Brasil - 1960: Sinopse Preliminar do Censo Demográfico. Rio de Janeiro.

-----. 1966a. Recenseamento Geral do Brasil - 1960: Censo Demográfico. Rio de Janeiro.

-----. 1966b. Recenseamento Geral do Brasil - 1960: Censo Agrícola. Rio de Janeiro.

-----. 1970. Divisão do Brasil em Micro-Regiões Homogêneas em 1968. Rio de Janeiro.

-----. 1972a. Recenseamento Geral do Brasil - 1970: Sinopse Preliminar do Censo Demográfico. Rio de Janeiro.

-----. 1972b. Cartogramas do Brasil. Rio de Janeiro.

-----. 1975a. Recenseamento Geral do Brasil - 1970: Censo Demográfico. Rio de Janeiro.

-----. 1975b. Recenseamento Geral do Brasil - 1970: Censo Agropecuário. Rio de Janeiro.

-----. 1979. Recenseamento Geral do Brasil - 1975: Censo Agropecuário. Rio de Janeiro.

-----. 1980. Produção Agropecuária Municipal - 1979. Rio de Janeiro.

-----. 1981. Recenseamento Geral do Brasil - 1980. Sinopse Preliminar do Censo Demográfico. Rio de Janeiro.

-----. 1983. Recenseamento Geral do Brasil - 1980. Censo Demográfico, Mão-de-Obra. Rio de Janeiro.

FUNDAÇÃO GETÚLIO VARGAS. 1978. Preços Recebidos pelos Agricultores (Brasil). Conjuntura Econômica 32(2): 71.

-----. 1983. Preços Recebidos pelos Agricultores (Brasil). Conjuntura Econômica 37(2): 71.

FUNDACION SHELL. 1961. Estudio de los Suelos Venezolanos con Fines de Diagnostico. Caracas.

GARFORTH, C. 1982. Reaching the Rural Poor: A Review of Extension Strategies and Methods. In Progress in Rural Extension and Community Development: Extension and Relative Advantage in Rural Development, G.E. Jones & M. Rolls (eds.), pp. 44-70. Chichester: John Wiley & Sons.

GEERTZ, C. 1963. Agricultural Involution. Berkeley, CA: University of California.

GEIDA (Grupo Executivo de Irrigação para o Desenvolvimento Agrícola). 1970. Plano Nacional de Irrigação. Brasília: MINTER.

GILBERT, A. 1974. Latin American Development: A Geographical Perspective. Hamondsworth: Penguin.

GLASS, G.V. & J.C. STANLEY. 1970. Statistical Methods in Education and Psychology. Englewood Cliffs, NJ: Prentice-Hall.

GODFREY, M. 1980. Is Dependency Dead? Bulletin 12(1): 1-4.

GOODMAN, D. 1981. Rural Structure, Surplus Mobilization and Modes of Production in a Peripheral Region: The Brazilian Northeast. In The Logic of Proverty. S. Mitchell (ed.), pp. 10-40. London: Routeledge & Kegan Paul.

GOODMAN, D. & M. REDCLIFT. 1981. From Peasant to Proletarian: Capitalist Development and Agrarian Transitions. Oxford: Basil Blackwell.

GORDON, D. 1972. Conservative, Liberal and Radical Approaches. In, Urban Economics: A Reader, D. Gordon (ed.), pp. 7-19. Cambridge, MS: Harvard University Press.

GOULD, P.R. 1963. Man Against His Environment: A Game Theoretic Framework. Annals of the American Association of Geographers 53: 290-297.

GOULET, D. 1983. The Shock of Underdevelopment. In The Struggle for Economic Development, M.P. Todaro (ed.), pp. 3-9. London: Longman.

GREGORY, J. 1975. Image of Limited Good or Expectation of Reciprocity? Current Anthropology 16(1): 73-92.

GRIFFIN, K. 1981. Land Concentration and Rural Poverty. New York: Holmes & Meier.

GROSS, D.R. 1970. Sisal and Social Structure in Northeastern Brazil. Unpublished Ph.D. Dissertation. Columbia University.

GUERRA, P.B. 1980. Açudes Públicos do Nordeste. Fortaleza: DNOCS.

GUIMARÃES NETO, L. 1975. Insatisfatória Utilização da Força de Trabalho em Atividades Produtivas no Nordeste. Recife: Banco do Nordeste do Brasil.

HALL, A.L. 1978. Drought and Irrigation in North-East Brazil. Cambridge: Cambridge University Press.

HANSEN, N.M. 1981. Development from Above: The Centre-Down Development Paradigm. In Development from Above or Below?: The Dialectics of Regional Planning in Developing Countries, W.B. Stöhr & D.R.F. Taylor (eds.), pp. 15-38. Chichester: John Wiley & Sons.

HASWELL, M.R. 1973. Tropical Farming Economics. London: Longman.

HARDIMAN, M. & J. MIDGLEY. 1982. The Social Dimensions of Development. Chichester: John Wiley & Sons.

HARRISS, J. & M. MOORE. 1984. Introduction to Special Issue on Development and the Rural-Urban Divide. Journal of Development Studies 20(3): 1-4.

HARVEY, C. et al. 1979. Rural Employment and Administration in the Third World. Aldershot: Gower.

HEATHCOTE, R.L. 1983. The Arid Lands: Their Use and Abuse. London: Longman.

HENFRY, C. 1984. Jaguar's Den: The Making of a Brazilian Peasantry and its Political Implications. Paper presented to the Social Movements in Latin America Conference, ILAS, London.

HENSHALL, J.D. 1971. Modelos de Atividad Agricola. In La Geografia y los Modelos Socio-Economicos, R.J. Chorley & D.Haggett (eds.). Madrid: Instituto de Estudos de Administration Local.

HENSHALL, J.D. & R.P. MOMSEN JR. 1974. A Geography of Brazilian Development. London: G. Bell & Sons.

HEWES, L. & JUNG, L. 1981. Early Fencing on the Middle Western Prairie. Annals of the American Association of Geographers 71 (2): 177-201.

HIDROSERVICE. 1971. Recuperação Hidrográfica da Bacia de Irrigação de São Gonçalo. São Paulo.

HIRSCHMAN, A.O. 1971. Unbalanced Growth: an Espousal. In Developing the Underdeveloped Countries. A.B. Mountjoy (ed.). pp. 129-141. London: Macmillan.

-----. 1979. Foreword. In Toward a New Strategy for Development, K.Q. Hill (ed.), pp. XV-XVIII. New York: Pergamon Press.

HODDER, B.W. 1973. Economic Development in the Tropics. London: Methuen.

HOEFLE, S.W. 1983. Continuity and Change in the Northeastern Sertão of Brazil. Unpublished D.Phil. Thesis, University of Oxford.

-----. 1985. Harnessing the Interior Vote: The Impact of Economic Change, Unbalanced Development and Authoritarianism on Local Politics of Northeast Brazil. Working Paper 19. London: Institute of Latin American Studies (in press).

HUNTER, G. 1969. Modernizing Peasant Societies: A Comparative Study in Asia and Africa. London: Oxford University Press.

IANNI, O. 1977. A Classe Operária Vai ao Campo. São Paulo: CEBRAP.

JOHNSON, A.W. 1971. Sharecroppers of the Sertão. Stanford: Stanford University Press.

-----. 1972. Individuality and Experimentation in Traditional Agriculture. Human Ecology 1(2): 149-60.

JONES, D.W. 1982. Location and Land Tenure. Annals of the Association of American Geographers 72(3): 314-337.

KASPRZYKOWSKI, J.W.A. & NOBRE, J.M.E. 1974. Possibilidades da Caprinocultura e Ovinocultura do Nordeste. Fortaleza: BNB/MEC.

KATZMAN, M.T. 1984. The Land and People of Northeast Brazil: Is Geography a Useful Guide to Development Policy? Economic Development and Cultural Change 32(3): 629-638.

KAY, G. 1975. Development and Underdevelopment: A Marxist Analysis. London: Macmillan.

KELLER, E.C.S. 1968. Regime de Exploração Agrícola. In Atlas Geográfico do Brasil, pp. III-5.1. Rio de Janeiro: IBGE.

KITCHING, G. 1982. Development and Underdevelopment in Historical Perspective. London: Methuen.

LAMBERT, J. 1969. Os Dois Brasis. São Paulo: Companhia Editora Nacional.

LEHMANN, D. 1982. Sharecropping Arrangements in a 'Peasant' Economy in Ecuador. Paper presented to the 44th International Congress of Americanists, Manchester.

LENIN, V.I. The Differentiation of the Peasantry. In Rural Development: Theories of Peasant Economy and Agrarian Change, J. Harriss (ed.), pp. 130-138. London: Hutchinson University Library.

LINS, R.C. 1976. A Bovinocultura no Nordeste. Recife: Instituto Joaquim Nabuco de Pesquisas Sociais.

LIPTON, M. 1977. Why Poor People Stay Poor: A Study of Urban Bias in World Development. London: Temple Smith.

-----. 1982. Why Poor People Stay Poor. In Rural Development: Theories of Peasant Economy and Agrarian Change, J. Harriss (ed.), pp. 66-82. London: Hutchinson University Library.

-----. 1984. Urban Bias Revisited. The Journal of Development Studies 20(3): 139-166.

LOPES, J.R.B. 1976. Do Latifúndio à Empresa: Unidade e Diversidade do Capitalismo no Campo. São Paulo: CEBRAP.

LOUREIRO, M.R.G. 1977. Parceria e Capitalismo. Rio de Janeiro: Zahar.

MACEDO, J.N. 1952. As Fazendas de Gado do Vale do São Francisco. Rio de Janeiro: Serviço de Informação Agrícola.

MAGNANINI, R.L.C. 1977. População. In Geografia do Brasil: Região Nordeste, pp. 135-207. Rio de Janeiro: Fundação IBGE.

MALASSIS, L. 1975. Agriculture and the Development Process. Paris: UNESCO.

MARTINEZ-ALIER, J. 1983. Sharecropping: Some Illustrations. Journal of Peasant Studies 10(2/3): 94-106.

MARTINEZ-ALIER, V. 1975. As Mulheres do Caminhão de Turma. Debate e Crítica 5: 59-85.

MATA, M. et al. 1973. Migrações Internas no Brasil. Rio de Janeiro: IPEA.

MATARRESSE, N. 1962. Prime Esperienze di Esercizio dell'Implianto Irriguo del Tara. Roma/Bari: Ente per lo Sviluppo della Irrigazione e la Transformazione Fondiaria in Puglia e Lucania.

McALLISTER, J. 1981. Rural Innovators: A Struggle for Power. In Extension Education and Rural Development: International Experience in Communication and Innovation, B.R. Crouch & S. Chamala (eds.), pp. 135-146. Chichester: John Wiley & Sons.

McGUIRE, R. & R.M. NETTING. 1982. Leveling Peasants? The Maintenance of Equality in a Swiss Alpine Community. American Ethnologist 9(2): 269-290.

MELLO, M.D. 1976. O Bóia-Fria: Acumulação e Miséria. Petrópolis: Vozes.

MELO, M.L. 1975. O Açúcar e o Homem. Recife: Instituto Joaquim Nabuco de Pesquisas Sociais.

-----. 1976. Proletarização e Emigração nas Regiões Canavieiras e Agrestina de Pernambuco. Paper presented to the II Encontro Nacional de Geógrafos Brasileiros, Belo Horizonte.

-----. 1978. Regionalização Agrária do Nordeste. Recife: SUDENE.

-----. 1980. Os Agrestes. Recife: SUDENE.

MELLOR, J.W. 1973. Contribuição para uma Teoria do Desenvolvimento Agrícola. In Agricultura e Desenvolvimento, J.Pastore (coord.), pg. 70-112. Rio de Janeiro: APEC.

MILLER, S. 1984. Middle-Scale Farmers of Northern Mexico. Paper presented to the Capitalist Agriculture in Latin America Conference, CLAS, Cambridge.

MINTER (Ministério do Interior). 1973. Plano Integral para o Combate Preventivo aos Efeitos das Secas no Nordeste. Brasília.

MINTER/DNOCS. 1976. II Plano Nacional de Desenvolvimento: Programa de Irrigação do Nordeste Semi-Árido (1976-1979). Fortaleza.

MOORE, M. 1984. Political Economy and the Rural-Urban Divide, 1767-1981. The Journal of Development Studies 20(3): 5-27.

MORGAN, W.B. 1977. Agriculture in the Third World. London: G. Bell & Sons.

MORGAN, W.B. & MUNTON, R.J. 1971. Agricultural Geography. London: Methuen.

MOUNTJOY, A.B. 1973. The Mezzogiorno. London: Oxford University.

MOURA, H.A. et al. 1975. Nordeste: Migrações Inter e Intra-Regionais 1960/1970. Recife: SUDENE/Banco do Nordeste do Brasil.

MUÑOZ, H. 1981. Introduction: The Various Roads to Development. In From Dependency to Development, H. Muñoz (ed.), 1-11. Boulder, CO: Westview Press.

MYRDAL, G. 1957. Economic Theory and Underdeveloped Regions. London: Ducksworth.

NEWBERY, D.M.C. 1975. The Choice of Rental Contract in Peasant Economies. In Agriculture in Development Theory. L.G. Reynolds (ed.), pp. 109-137. New Haven: Yale University Press.

NIMER, E. 1966. Circulação Atmosférica. In Atlas Geográfico do Brasil, pp. II-6. Rio de Janeiro: IBGE.

-----. 1977. Clima. In Geografia do Brasil: Região Nordeste, pp. 47-84. Rio de Janeiro: Fundação IBGE.

-----. 1979. Pluviometria e Recursos Hídricos de Pernambuco e Paraíba. Rio de Janeiro: Fundação IBGE.

NURKSE, R. 1971. The Theory of Development and the Idea of Balanced Growth. In Developing the Underdeveloped Countries, A.B. Mountjoy (ed.), pp. 115-128. London: Macmillan.

OLIVEIRA, F. 1975. A Economia Brasileira: Crítica à Razão Dualista. Seleções CEBRAP 1: 5-78.

-----. 1977. Elegia para uma Re(li)gião: SUDENE, Nordeste, Planejamento e Conflitos de Classe. Rio de Janeiro: Paz e Terra.

OVERSEAS DEVELOPMENT COUNCIL. 1979. U.S. & World Development Agenda. New York: Praeger.

PAIVA, R.M., SCHITAN, S. & FREITAS, C.F.T. 1976. Setor Agrícola do Brasil. Rio de Janeiro: Forense.

PATRICK, G.F. 1972. Desenvolvimento Agrícola do Nordeste. Rio de Janeiro: IPEA/INPES.

PEARSE, A. 1975. The Latin American Peasant. London: Frank Cass.

-----. 1980. Seeds of Plenty, Seeds of Want: Social and Economic Implications of the Green Revolution. Oxford: Clarendon Press.

PELLERIN, G. 1972. Oferta e Demanda de Mão-de-Obra no Nordeste. Recife: SUDENE.

PETERSON, D.F. 1970. Water in the Deserts. In Arid Lands in Transition, H.E. Dregne (ed.), pp. 15-30. Washington, DC: American Association for the Advancement of Science.

PIERSON, D. 1972. O Homem no Vale do São Francisco. Rio de Janeiro: SUVALE.

PINHEIRO, I.C.M. 1959. Notas sobre as Secas. Boletim DNOCS 20(6).

PONTES, J.O. 1978. O Trabalho do DNOCS e o Programa de Irrigação no Nordeste Semi-Árido. Fortaleza: DNOCS.

PROJETO ASA BRANCA. n.d. Estudos Sócio-Econômicos - Relatório Geral: Rio Brígida e Terra Nova. Recife.

QUEIROZ, M.I.P. 1973. O Campesinato Brasileiro. Petrópolis: Vozes.

-----. 1977. Os Cangaceiros. São Paulo: Duas Cidades.

REDCLIFT, M.R. 1984. 'Urban Bias' and Rural Poverty: A Latin American Perspective. The Journal of Development Studies 20(3): 123-138.

REID JR., D.G. 1973. Sharecropping as an Understandable Market Response: the Postbellum South. Journal of Economic History 33: 69-83.

RINKS, P.A. 1978. Rural Changes in Java: An End to Involution? Geography 63(278): 31-36.

ROBERTS, B. 1978. Cities of Peasants. London: Arnold.

RÖLING, N.G. et al. 1981. The Diffusion of Innovations and the Issue of Equity in Rural Development. In Extension Education and Rural Development: International Experience in Communication and Innovation, B.R. Crouch & S. Chamala (eds.), pp. 225-236. Chichester: John Wiley & Sons.

ROSTOW, W.W. 1960. The Stages of Economic Growth. Cambridge: Cambridge University Press.

ROY, P. 1982. Extension with the Disadvantaged: A Radical View. In Progress in Rural Extension and Community Development: Extension and Relative Advantage in Rural Development, G.E. Jones & M. Rolls (eds.), pp. 71-86. Chichester: John Wiley & Sons.

RUSSELL, E.W. 1973. Soil Conditions and Plant Growth. London: Longman.

RUTHENBERG, H. 1980. Farming Systems in the Tropics. Oxford: Clarendon Press.

SÁ JR., F. 1975. O Desenvolvimento da Agricultura Nordestina e a Função das Atividades de Subsistência. Seleções CEBRAP 1: 79-134.

SAHLINS, M. 1966. Tribal Societies. Englewood Cliffs, NJ: Prentice-Hall.

-----. 1974. Stone Age Economics. London: Tavistock.

SANDERS, D. 1972. Population Pressure and Agrarian Decline in Mesoamerica. In, Population Growth, B. Spooner (ed.), pp. 102-151. Cambridge, MS: MIT Press.

SANDERS JR., J.H. & HOLLANDA, A.D. 1977. Elaboração de Nova Tecnologia para os Pequenos Agricultores: Um Estudo de Caso na Zona Semi-Árida do Nordeste Brasileiro. Revista Econômica do Nordeste 8 (4): 627-656.

SANTOS, L.B. 1962. Clima. In Grandes Regiões Meio-Norte e Nordeste. M.G.C. Hereda & A.J.P. Domingues (eds.), pp. 113-134. Rio de Janeiro: IBGE.

SANTOS, T. 1983. The Structure of Dependence. In The Struggle for Economic Development, M.P. Todaro (ed.), pp. 68-75. London: Longman.

SCHUMACHER, E.F. 1973. Small is Beautiful. London: Blond & Briggs.

SHANIN, T. 1982. Polarization and Cyclical Mobility: The Russian Debate over the Differentiation of the Peasantry. In Rural Development: Theories of Peasant Economy and Agrarian Change, J. Harriss (ed.), pp. 223-245. London: Hutchinson University Library.

SHERIDAN, R. 1983. The Colorado River. Smithsonian 12(2): 13-19.

SILVA, J.F.G. 1978. Estrutura Agrária e Produção de Subsistência na Agricultura Brasileira. São Paulo: HUCITEC.

SILVA, M.M. & D.M.A. LIMA. 1982. O Sertão Norte. Recife: SUDENE.

SMITH, D.M. 1979. Where the Grass is Greener. Living in an Unequal World. Harmondsworth: Penguin.

STAVENHAGEN, R. 1981. The Future of Latin America: Between Underdevelopment and Revolution. In From Dependency to Development, H. Muñoz (ed.), pp. 207-223. Boulder, CO: Westview Press.

STEFFAN, E.R. 1977. Hidrografia. In Geografia do Brasil: Região Nordeste, pp. 111-133. Rio de Janeiro: Fundação IBGE.

STERN, P.H. 1979. Small Scale Irrigation: A Manual Of Low-Cost Water Technology. London: Intermediate Technology Publications.

STEWARD, J. 1955. Theory of Culture Change. Urbana, IL: University of Illinois.

STIGLITZ, J.E. 1974. Incentives and Risk Sharing in Sharecropping. Review of Economic Studies 41: 219-256.

STÖHR, W.B. 1981. Development from Below: The Bottom-Up and Periphery-Inward Development Paradigm. In, Development from Above or Below? The Dialectics of Regional Planning in Developing Countries, W.B. Stöhr & D.R.F. Taylor (eds.), pp. 39-72. Chichester: John Wiley & Sons.

SUDENE (Superintendência do Desenvolvimento do Nordeste). 1963. Normais Climatológicas da Área da SUDENE. Recife.

-----. 1969. SUDENE Dez Anos. Recife.

-----. 1973. Átlas dos Recursos Naturais. Recife.

-----. 1974. Recursos Naturais do Nordeste: Investigação e Potencial. Recife.

-----. 1977. Projeto Sertanejo. Recife.

-----. 1979. Recursos Naturais do Nordeste: Investigação e Potencial. Recife.

SUDENE/ASMIC. 1967. Estudo Geral de Base no Vale do Jaguaribe: Hidrogeologia. Recife.

SUTCLIFFE, B. 1984. Industry and Underdevelopment Re-examined. Journal of Development Studies 21(1): 121-133.

SYMONS, L. 1972. Agricultural Geography. London: G.Bell & Sons.

TAYLOR, L. 1984. The Rise of Medium-Scale Dairy Farming in the Department of Cajamarca, 1940-1984. Paper presented to the Capitalist Agriculture in Latin America Conference, CLAS, Cambridge.

THORNE, W. 1970. Agricultural Production in Irrigated Areas. In Arid Lands in Transition, H.E. Dregne (ed.), pp. 31-56. Washington, DC: American Association for the Advancement of Science.

USDA (United States Department of Agriculture). 1951. Soil Survey Manual. Washington, DC: Government Printing Office.

-----. 1953. Diagnoses and Improvement of Saline and Alkali Soil. Washington, DC: Government Printing Office.

-----. 1975. Soil Taxonomy. Washington, DC: Government Printing Office.

VALVERDE, O. 1964. Geografia Agrária do Brasil. Rio de Janeiro: MEC.

VALENZUELA, J.S. & A. VALENZUELA. 1981. Modernization and Dependency: Alternative Perspectives in the Study of Latin American Underdevelopment. In From Dependency to Development, H. Muñoz (ed.), pp. 15-41. Boulder, CO: Westview Press.

WALLERSTEIN, I. 1981. Dependence in an Interdependent World: The Limited Possibilities of Transformation Within the Capitalist World Economy. In From Dependency to Development, H. Muñoz (ed.), pp. 267-293. Boulder, CO: Westview Press.

WARMAN, A. 1982. 'We Come to Object': The Peasants of Morelos and the National State. Baltimore: The Johns Hopkins University Press.

WHARTON JR., C.R. 1971. Risk, Uncertainty, and the Subsistence Farmer. In, Economic Development and Social Change, G. Dalton (ed.), pp. 566-574. Garden City, NY: The Natural History Press.

WHITE, L. 1959. The Evolution of Culture. New York: McGraw-Hill.

WILLEMSEN, E.W. 1974. Understanding Statistical Reasoning. San Francisco, CA: W.H. Freeman.

WITHERS, B. & VIPOND, S. 1974. Irrigation: Design and Practice. London: B.T. Batsford.

WITTFOGEL, K. 1959. The Theory of Oriental Society. In Readings in Anthropology, M. Fried (ed.). New York: Cowell.

WOLF, E.R. 1966. Peasants. Englewood Cliffs, NJ: Prentice-Hall.

-----. 1982. Europe and the People without History. Berkeley, CA: University of California Press.

XOLOCOTZI, E.H. 1970. Mexican Experience. In Arid Lands in Transition, H.E. Dregne (ed.), pp. 317-343. Washington, DC: American Association for the Advancement of Science.

YUDELMAN, M. & HOWARD, F. 1970. Agricultural Development and Economic Integration in Latin America. London: George Allen & Unwin.

ZARUR, J. 1946. A Bacia do Medio São Francisco. Rio de Janeiro: IBGE.