INADVERTENTLY REACHING THE POOR: THE DIFFUSION OF SMALL SCALE IRRIGATION IN NORTHEAST BRAZIL

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Abstract

Governments have long tried to promote productivity in agriculture through a variety of programs aimed at diffusing irrigation, some of which targeted small farmers. However, irrigation programs can be unsuccessful in spreading irrigation, or they can fail reaching small farmers. This study draws on a successful case of diffusion of small scale individual irrigation in Northeast Brazil to identify under which conditions irrigation programs benefit small farmers, directly or indirectly. I argue that irrigation programs reach small farmers when they a) promote general-purpose equipment, such as flood irrigation, rather than crop-specific equipment, such as sprinklers, b) promote simple, small scale equipment, such as small pumps and motors, shallow tubewells, and earthen ditches, c) adapt to regional characteristics and individual land plot attributes, such as water table height, plot slope and shape, d) elicit a local supply of small scale general-purpose equipment and repair services, e) create an arena for exchange of knowledge about and solutions to specific problems among researchers and extension officers, and f) create a committed bureaucracy. Nation-wide one-task programs can end up performing these functions better than multi-task regional programs. Nation-wide one-task programs have to adapt to specific local conditions in diverse micro-regions of the country, such as alluvial valleys. Regional multi-task programs, on the contrary, tend to ignore the internal diversity of the problem region they focus on.

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TABLE OF CONTENTS

1. INTRODUCTION

The positive effects of irrigation on agricultural production and farmers' incomes are well known.[1] Also well known are the positive effects of small farmers' increased production and incomes on productivity and the overall economy.[2] How to facilitate small farmers' access to irrigation, instead, remains problematic. Unlike large farmers, small farmers lack capital, access to bank credit, technical knowledge, and market channels. Since investment in and maintenance and operation of irrigation equipment is expensive, small farmers usually do not invest in irrigation, even when such investment would yield substantial gains.

Governments follow different patterns in facilitating small farmers' irrigation investment. The main types of irrigation, and the corresponding types of government intervention in irrigation diffusion, are presented in table 1. Public irrigation projects constitute one option: the government builds and operates large collective water distribution systems, either on land already belonging to small farmers or on land it expropriates and distributes to landless peasants and small farmers. Alternatively, governments provide or encourage small scale collective projects for comparatively small groups of farmers (maximum 30 users). Finally, governments promote private individual irrigation, i.e., irrigation projects on the private land of individual farmers . Each approach encounters different types of problems. In collective projects, both large and small, farmer groups fail to perform proper maintenance and "steal" water; in addition, agriculture often has a low productivity, and does not allow full cost recovery. Under appropriate conditions, however, collective projects have proven to be able to overcome their problems and perform well.[3] In addition to the collective action problems they encounter, public projects tend to be more expensive than private irrigation, drawing heavily from government financial and administrative resources; moreover, when they entail land expropriation,

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[1] Irrigation increases the number of harvests per year, expands the demand for labor and makes it less seasonal, and reduces the risks farmers face, by diminishing their dependency on rainfall. Irrigation allows farmers to substitute high-value cash crops such as fruits for subsistence crops such as cassava, transforms crops such as rice or beans from rainfed subsistence crops into irrigated cash crops, and, in conjunction with fertilizer use, increases yields.

[2] Production of foodstuff and wage goods for the domestic market grows, as well as the production of raw materials for agro-processing industries. Small farmers' ability to save expands private savings. Higher incomes available to small farmers create domestic markets for industrial and artisan output. Improved nutrition augments labor productivity; further gains in productivity result from small farmers' more efficient use of resources than large farmers Timmer 1992; Binswanger and Elgin 1990:343 shows that in Brazil, like in other parts of the world, small farmers are more efficient than large farmers.

large public projects elicit strong political opposition from landed elites and small farmers. Programs promoting private irrigation, albeit less expensive for the public sector, encounter difficulties in reaching small farmers and in directly benefiting the poor and the landless.

Table 1. Typologies of irrigation programs

	Individual Irrigation Programs	Small Collective Irrigation Programs	Large Public Projects
Type of Irrigation	Private Individual Irrigation	Private Collective Irrigation	Large Public Projects
Infrastruct Individual/ Collective	Individual	Collective	Collective
Infrastruct Large/Small	Large/Small	Small	Large
Implement of Infrastruct	Individual Farmer	Public Agency with Farmers' Participation	Public Agency (Federal or State)
Land Regime	Private Land: Owned or Rented	Private Land; Occasional Attempts at Collective Farming	Expropriated Land
Typical Components	Credit/Grants for Individ. Equipment Extension services Rural Electrif., Roads, Hydraulic Infrastr. (River Dams, Drainage), Operation Credit	Communal Works Rural Electrification Training, Roads Drainage, Extension Services, Operation Credit	Construction of Irrig. Infrastructure and Equipment, Subsidized Inputs Extension Services, Operation Credit
Beneficiary Funding	Main Source of Funding	10% Contribution in Kind or Labor	Insignificant
Government Funding	Subsidized credit, Public Infrastructure	Irrigation Infr. Subsidized credit	Whole Project
Targeting	Not necessarily	Small Farmers	Landless, Small Farmers
Water Mngmnt	Individual	Group of Farmers	Public Agency Group of Farmers

Small farmers encounter difficulties in accessing public sector individual irrigation programs, which are usually better suited to the needs of large farmers than to those of small farmers. For example, irrigation programs subsidize either bank credit that small farmers cannot access for lack of collateral, or large irrigation motors and pumps that are inappropriate for small plots. Economies of scale in the construction of rural electric lines exclude small farmers from access to electric power, while extension agencies mainly serve

[3] Ostrom 1990 and 1994, Moore 1989.

large farmers. As a result, many irrigation programs promoting individual irrigation do not benefit small farmers.

Based on fieldwork in Northeast Brazil, my thesis draws lessons about how individual irrigation programs can facilitate small farmers' access to irrigation.[4] My study is based on evidence from the successful case of the Lower Jaguaribe Valley in the state of Ceará, which I chose because small and very small farmers had gained access to individual small scale irrigation equipment.[5] In the semi-arid areas of the Northeast, higher private irrigation costs (US$ 3500/ha) than in the South (only US$ 650/ha) prevent farmers, especially small ones, from investing in irrigation. Higher irrigation costs result from water scarcity and the crystalline soils, that make it necessary to pump ground water from deep wells, and to transport pumped water to distant locations.[6] Moreover, higher evaporation rates[7] and lower and more irregular rainfalls increase the quantity of water that farmers have to pump, raising their operation costs.

To diffuse irrigation among small farmers in the Northeast, the Brazilian government fully funded and directly undertook large public irrigation projects, e.g. expropriating land to settle landless families, building large collective infrastructure for water extraction and distribution, providing inputs and extension services. These federal projects have proven more costly than private ones both in the Northeast and in the South,[8] and most of them have not been very successful, according to several evaluations,[9] the extension agents in the field, and officials from the federal agency that implemented the projects.[10]

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[4] I define large farmers as those who farm more than 20 ha of both irrigated and non-irrigated land; farmers cultivating between 10 and 20 ha are medium farmers; farmers with plots between 2 and 10 ha are small, and farmers whose land plots are less than 2 ha are very small (e.g., Todaro 1981:19 uses 2 ha as a threshold). The farmers that I define as "large" and "medium" here are usually considered small. However, especially the large ones, constituted the village elite, and were often among the largest employers in the Jaguaribe Valley, where I conducted my research. The farmers that I define very small have to hire themselves out to make a living, do not have--and fear--access to bank credit, and find themselves trapped in clientelistic relations with the larger farmers. Moreover, the definition I use fits the classification used by the Ceará state agency for water resources, classifications in the literature and the land ownership, social, and economic conditions in the Jaguaribe Valley. In the valley, land ownership is more equally distributed than in the surrounding semi-arid area: only few agricultural entrepreneurs farm more than 100 ha. For example, in one of the municipalities, very large farmers (more than 100 ha) own 51% of agricultural land, while the average for Ceará is 67% of agricultural land.

[5] In the lower Jaguaribe Valley, the percentage of irrigated land on the total agricultural land is 1.4%, as opposed to 0.6 in the whole of Ceará (data from Ceará state water resources agency).

[6] WB 1990: 8. The water table is at a level of 80 m. in the Chapada do Apodi, on the border between Ceará and Piauí, and 100 m. in the Serra da Ibiapaba, a mountain region in Ceará.

[7] Evaporation rates are higher in the Northeast than in the South due to lower atmospheric humidity and higher temperatures than in the South.

[8] Federal large public projects cost US$ 6,500/ha, vs. a cost of private irrigation of US$ 3,500/ha in the Northeast and US$ 650/ha in the South; WB 1990.

[9] WB 1990, França 1993, Biserra 1995

[10] However, the Petrolina/Juazeiro area, where the government implemented large irrigation projects and

Outside the Northeast, on the contrary, the development of irrigation has been the result of private initiative or of a combination of private initiative and public intervention. Public agencies built rural roads and provided rural electrification and drainage works, while farmers bought their own equipment with subsidized credit.[11]

The diffusion of irrigation in the Lower Jaguaribe Valley stands out in this panorama because it had characteristics similar to the diffusion of irrigation outside the Northeast. Even though large public irrigation projects are located in the Valley, the diffusion of irrigation among small farmers was less an outcome of centralized public irrigation programs involving land expropriation and settlement of small farmers than of the farmers' private initiative, with key inputs from public intervention. The Lower Jaguaribe Valley is not unique in the Northeast: other alluvial valleys in Northeast Brazil show similar stories of diffusion of irrigation.[12]

Moreover, in the lower Jaguaribe Valley, unlike the surrounding semi-arid land (sertão), small farmers have access to irrigation equipment, to repair services, and to the necessary technical knowledge as well as large and medium farmers.[13] Both small and large farmers use simple equipment: they utilize small pumps and motors (ranging from 3 to 15 CV) to extract ground water from individual plastic or cement wells (usually 22 m. deep) or surface water from rivers; earth ditches, cement canals, or plastic pipes distribute water in the fields. In the middle of semi-arid[14] and drought-prone[15] Ceará, in Northeast Brazil, the Lower Jaguaribe Valley differs from the rest of the state because neither the seven-month long dry season, nor even droughts stop production of beans, rice, corn, and fruit, such as traditionally-grown bananas and lemons, and guavas--introduced in the last ten years.

This situation is not the fortuitous result of natural forces. On the contrary, water has not always been available in the Lower Jaguaribe Valley, neither have its farmers always had irrigation equipment. The present situation is the outcome of a thirty-year long process, that included public sector interventions such as the construction of dams on the two major rivers of the region--Jaguaribe and Banabuiú--the creation of the rural electric power network, a policy of low electric power prices for irrigation, and successful state

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large agrarian reform areas had considerable success.

[11] WB 1990

[12] WB 1990. In Ceará, for example, the Curú Valley presents important similarities with the Jaguaribe Valley.

[13] Data from the state water agency.

[14] Annual rainfall varies between 400 mm/year and 800 mm/year, all concentrated in a five-month rainy season from January to June.

[15] In Ceará, there are about two severe droughts per decade.

programs aimed at spreading small-scale irrigation techniques and equipment.[16] These interventions facilitated small farmers' autonomous investment in simple small scale irrigation equipment, such as small motors and pumps, cement and plastic pipes for wells and for water distribution. Public intervention raised the water table, made water available year-round, prompted rural electrification, created public- and private-sector expertise in irrigated agriculture, subsidized demand and elicited supply for simple small scale equipment that farmers could adapt to a wide range of crops, such as fruit, rice, and beans. As a result, small-scale irrigation equipment became available in the small interior towns and in the rural areas, both small and large farmers obtained connections to the electric network, and know-how about new crops and irrigation techniques spread among all the farmers, rather than only among large farmers.

This thirty-year long process introduced an unusual bias in favor of small scale equipment rather than large motors and pumps. As a result of this bias, small and very small farmers (irrigating less than 2 ha) could buy irrigation equipment appropriate to their needs either by drawing on their savings or by getting credit from equipment dealers and middlemen. A first step in the creation of this bias in favor of small scale equipment was the damming of the Banabuiú and the Jaguaribe rivers in the 1950s, and their regularization completed in the early 1980s, by DNOCS (the federal agency for public works against droughts). These interventions raised the water table and therefore lowered the cost of pumping water. With the resulting higher water table, motors as small as 3 or 11 CV sufficed to pump enough water to irrigate even water-intensive crops such as irrigated rice.

The diffusion of irrigation in the lower Jaguaribe Valley presented two unusual characteristics: first, public programs benefited small farmers even when their primary objective was not targeting them. This is unusual, because often irrigation programs do not manage to reach small farmers even when specifically targeting them. On the contrary, in the Lower Jaguaribe Valley public intervention reached small farmers indirectly, by creating a local supply for small scale equipment, and inadvertently, while trying to solve other problems. For example, the main objective of the damming and regularization of rivers was the creation of a stable supply of water for both urban and rural areas, and not the raising of the water table to a level that permitted the use of small motors and pumps. By attributing advantages to large farmers, programs enhanced, rather than jeopardize, the small farmers' access to irrigation. For example, the focus on small scale irrigation benefited primarily large farmers, e.g., by allowing them to make incremental investments that minimized investment risks. As a side effect, local availability of small scale equipment permitted small farmers to buy the equipment on their own.

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[16] World Bank 1990: 6.

Second, a nation-wide program aiming at a very specific environment, river lowlands, resulted more successful in spurring diffusion of irrigation than the programs aiming at reducing territorial imbalances between the Northeast and the rest of the country. The most successful program in the Valley, PROMOVALE (Program for the Rural Valorization of the Lower and Medium Jaguaribe Valley), was part of a nation-wide sectoral program, PROVARZEAS (Program for Utilization of Irrigable River Flood Plains). Indeed, instead of concentrating its resources in the Northeast, PROVARZEAS operated in such different environments as the Center-West savannas and the South-eastern wet lowlands. It focused on the Southern states: 65% of the area irrigated and/or drained with support from PROVARZEAS between 1981 and 1986 is in Southern states. PROVARZEAS aimed at a very specific environment all over Brazil--the wet lowlands at the river margins, which in the 1970s were not cultivated because of their severely poor drainage. PROVARZEAS intended to a) solve the problem of drainage in the wet river lowlands, and b) exploit their capacity for irrigated agriculture.

In the case of PROVARZEAS, a sectoral policy carefully adapted to the specific characteristics of each region worked better at spurring local development than the regional irrigation programs. Success originated from the program's very narrow focus, that allowed program managers to concentrate on just one very specific thing, in this case promoting the agricultural exploitation of river lowland through land systematization, drainage, and irrigation. In regional programs, instead, managers have to perform many different tasks in the same area. Nation-wide sectoral programs, moreover, provide an arena for exchanges of experiences--e.g., on the results of different irrigation project designs--among professionals who are working on the same tasks across the country.

I collected the evidence for my thesis during fieldwork in Ceará, Brazil, in the summer of 1995. In the lower Jaguaribe Valley, I visited the municipalities of Limoeiro do Norte (564 km^2, 41,700 inhabitants), Quixeré (598 km^2, 13,801 inhabitants), and Russas (1,500 km^2, 46,566 inhabitants). I chose these municipalities because they were the main targets of past irrigation programs and because there the irrigation tradition is stronger: the percentage of irrigated area on agricultural area is 0.9% in Quixeré, 1.2% in Russas, and 4.9% in Limoeiro do Norte, well above the 0.6% value for the whole of Ceará. In these municipalities, I visited 6 rural communities: Arraial, Corrego de Areia, Miguel Pereira, Barreiras, Quixaba, Morros. In the rural communities I conducted 56 open-ended interviews with farmers and sat in community meetings. I also had an opportunity to participate in the community life, and to talk with the farmers' families, with social workers, local teachers, and extension agents. In the municipalities, I interviewed extension agents, middlemen, irrigation equipment dealers, private consultants, local

politicians, managers and officials from public banks, the state water agency, COERBA (Lower Jaguaribe Valley Rural Electrification Cooperative), and COELCE (Electric Company of the State of Ceará). In the state capital of Ceará, Fortaleza, I interviewed the presidents of the lower Jaguaribe organization of fruit producers and of the organization of the rural electrification cooperatives (FECOELCE, Federation of the Rural Electrification Cooperatives of the state of Ceará). I also interviewed state officials from the Planning, Agriculture, and Water state Agencies, and officials of the Ceará electric company. In Brasilia, I interviewed the federal officials that initiated PROVARZEAS.

My thesis is organized as follows: in chapter 2 I provide background information on the lower Jaguaribe Valley and on irrigation programs. In chapter 3 I show the mechanisms that made irrigation programs successful. The fourth chapter explains how public intervention indirectly benefited small and very small farmers and created a conducive environment for their autonomous investment in irrigation. I draw conclusions in chapter 5.

2. The Lower Jaguaribe Valley

With a population of 6.4 million people, Ceará ranks as the third largest and most populated state among the 9 states of poor and semiarid Northeast Brazil.[17] [18] With 19% of the area and 30% of population of Brazil, the Northeast concentrates two thirds of the Brazilian rural poor.[19] In this panorama, Ceará fares far below the whole of Brazil: Ceará GDP per capita was 54% of the national GDP per capita in 1992, the illiteracy rate was as high as 61% in 1988, and life expectancy was 54 years.[20]

The lower Jaguaribe Valley includes part of the territory of 10 of the 178 municipalities of Ceará.[21] These municipalities have a total area of 10,000 km^2 (7% of total state area), comprising both the lower alluvial valleys of the two major rivers, Jaguaribe and Banabuiú, and the surrounding semiarid sertão. The municipalities' population is 250,000 (4% of total Ceará population).[22] Population is concentrated in the alluvial valleys, and more specifically along the "avenidas rurais", linear villages along the roads in the alluvial valleys of the rivers.[23]

In Ceará, irrigated land (86,783 ha) is only a very small fraction (0.6%) of cultivated area (13,782,500 ha).[24] However, Ceará is one of the three states in the Northeast that concentrated most of the region's irrigated land: in 1985, according to the agrarian census, irrigated area in Ceará was 67,000 ha, 17% of the Northeast total, the third highest in the Northeast. [25] [26] Within Ceará, the lower Jaguaribe Valley has good potentialities for development of irrigation: even though it is a tiny 1.4%, the percentage of irrigated area (21,293 ha) on total agricultural area (1,572,300 ha) in the lower Jaguaribe Valley is still higher than the Ceará percentage, where irrigated area is only 0.6% of agricultural area. This comparatively higher percentage of irrigated land results from the diffusion of

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[17] The Northeastern states are: Maranhão, Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe, Bahia, and the Northern part of Minas Gerais.

[18] The population of Ceará is 15% of Northeast population (42,500,000).

[19] The relative poverty of the Northeast is evident from social and economic indicators such as: GDP per capita (55% of national GDP per capita in 1992), illiteracy rate (38% vs. a national rate of 20%) (WB 1995), life expectancy (58.8 years in the Northeast, vs. 64.9 nationally), labor productivity (half the national average), household access to sanitation (84% of household lacking it, compared to 52% in whole Brazil) and water supply (58% of households lacking access, vs. 28% nationally) (World Bank 1995).

[20] Governo do Estado do Ceará 1994

[21] Alto Santo, Ibicuitinga, Limoeiro do Norte, Quixeré, Tabuleiro do Norte, São João do Jaguaribe, Morada Nova, Russas, Jaguaruana, Palhano.

[22] Governo do Estado do Ceará 1995

[23] Interview with the state Secretary for water resources, Fortaleza July 1995, and direct observation. Census data do not discriminate between the semi-arid area and the alluvial valleys.

[24] Data of Ceará state agency for water resources.

[25] In the same year, 1985, Bahia had 26% and Pernambuco 20% of all irrigated land in the Northeast.

individual irrigation as well as from the presence in lower Jaguaribe of large public collective irrigation projects, such as the irrigation perimeter of Morada Nova. The river basins in the Lower Jaguaribe Valley have a more equal land distribution than the surrounding semi-arid area, the sertão, with its poor soils and water scarcity.

Irrigation Programs in the Lower Jaguaribe Valley

The lower Jaguaribe Valley has been the object of a number of public interventions aimed at spreading irrigation. Almost all types of irrigation that characterize diffusion of irrigation in Brazil are present in the Lower Jaguaribe Valley: large collective public projects such as Morada Nova, and Quixaba (Limoeiro do Norte); small collective irrigation on private land that received substantial support from the government, for example CAMPOVERDE; individual irrigation programs that provided credit, extension services, drainage, and rural electrification to private individual farmers, namely PROMOVALE; large individual irrigation on private land (more than 100 ha, producing high quality tropical fruit such as cantaloupes for the European and the US counterseason markets). Public intervention other than irrigation programs influenced the diffusion of irrigation in the Valley: for instance the damming of the two major rivers of the region, Jaguaribe and Banabuiú, created a steady availability of water and raised the water table, permitting extraction of both surface water from the rivers and of groundwater through shallow tubewells.

The effect of these interventions was to directly provide small and large farmers with access to irrigation, and to create conditions that facilitated small farmers' own initiative. In Table 2.2, I show the main characters of the public sector interventions that most contributed to diffuse small scale irrigation in the lower Jaguaribe Valley. I provide factual information only about the programs I use as examples for my arguments.

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[26] Ramos de Souza, Magalhaes 1995:195

Table 2.#
Public Interventions in the lower Jaguaribe Valley

	Dams	Quixaba	Morada Nova	Provarzeas	Promovale	Rural Electrific	Campo verde	NDRP	Kits	Banks
Type	Public Infrastructure	Public Project	Public Project	Individual Irrigation Program	Individual Irrigation Program	Infrastruct	Small CollectIrrig Program	Small CollectIrri Program	Individual Irrigation Program	Individual Irrigation Program
Started	1956 1960	1932	1970s	1981	1980	1980	1983	1983	1989	
Ended	1960s	1970	Present	1989 Present (on paper)	1986	Mid-1980s Present		Present	1990	Present
Agency	DNOCS		DNOCS	Ministry of Agriculture	State Agriculture Agency	COELCE COERBA	State Agric. Agency	State Plan. Agency	State Water Agency	Banks
Funding	Federal		Federal	Federal Government FAO, GTZ	Sudene, World Bank, Provarzeas, Federal Funds Ceará State, Polonordeste	Promovale State Publ. Banks		World Bank		Federal/ State
Area		Municip. Of Limoeiro	Municip of Morada Nova	Flood Plains in Whole Brazil	Lower and Medium Jaguaribe, Curú Valley	Rural Areas along Rivers	Lower & Medium Jaguaribe Caririí	Northeast Brazil	Whole Ceará	North-East
Design				Customized	Customized		Custom.	Custom.	Standard	Custom
Design &Equipment	Centra-lized	Centralized	Centralized	Decentralized	Decentralized		Centralized Particip.	Particip.	Centra-lized	Decen-tralized
Grant/Loan				Loans	Loans	Loans	Grants	Grants	Loans	Loans
Indiv/Coll.		Coll.	Coll.	Ind.	Ind.		Coll.	Coll.	Ind.	Ind/Coop
Targeting		Small/ Landless	Small/ Landless	No	Not strong	No	Groups of Small	Groups of Small	Small/ Medium	No
Beneficiary		Small/ Landless	Small/ Landless	Some Large Medium/Small	Large/ Medium SomeSmall	Large/ Medium/ Small	Small	Small	Large/ Medium	Large/ Medium Some Small
Multi-Component		Yes	Yes	Irrigation	Yes		Yes		Irrigation	

•PROVARZEAS, a nation-wide program of the Ministry of Agriculture, provided farmers in flood plains all over Brazil with credit, rural infrastructure (roads, rural electrification, and drainage works), and extension services, particularly project design. It did not aim at correcting regional imbalances: rather, only about 1/10 of PROVARZEAS resources went to the Northeast between 1981 and 1987.[27] Moreover, even though its primary objective was not to target small farmers, PROVARZEAS mainly benefited them.[28]

PROVARZEAS was created in 1975 in Minas Gerais by a German agronomist working for GTZ (the German aid agency), who had the vision of using simple and low cost techniques to expand production of basic foodstuff such as rice and grain to the then unused wet river lowlands. PROVARZEAS became a federal program in 1981, and then expanded to other states with environments as diverse as the Center-West savannas and the semi-arid Northeast.

PROVARZEAS did not impose a standard project design on farmers. First, state managers and technicians adapted the program to the characters of the state valleys the state programs targeted. For instance, in Ceará federal and state professionals favored small scale and technically simple techniques such as earthen ditches or cement canal and small scale pumps and motors. In Santa Catarina or in the Rio Grande do Sul, instead, the program financed massive and capital-intensive drainage works and promoted advanced irrigation machinery such as large sprinklers. PROVARZEAS lent many organizational features to PROMOVALE, e.g. the training system for farmers and technicians.

• PROMOVALE, a state irrigation program, aimed at spurring agriculture in the Lower Jaguaribe Valley. The then vice-governor and later governor of Ceará, Manuel de Castro, started the program in 1980. He intended to benefit his region of origin, that had remained outside a world Bank-funded large policy effort focused on Ibiapaba, a mountain region.

PROMOVALE had numerous components: a) creation of infrastructure, including rural electrification, river regularization, increases in storage capacity, marketing infrastructure; b) diffusion of improved seeds; c) livestock improvement; d) upgrading of technical expertise of extension agents and of farmers' knowledge; e) provision of subsidized bank credit (35% interest rate) and extension services for small-scale individual

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[27] Ministerio da Agricultura 1988

[28] WB 1990. Indeed, some of the PROVARZEAS documents state that the program aimed at benefiting small and medium farmers. However, my interviews show that the main objective of the program was to increase agricultural productivity and production, particularly of grains and beans in alluvial valleys, where often landownership is less concentrated.

irrigation; f) provision of land title to farmers. PROMOVALE promoted small scale flood irrigation for increases in production and productivity of bananas, beans, and rice.

The creation of infrastructure and the distribution of land titles helped PROMOVALE reach small farmers: the distribution of land tenure titles has the potentiality to improve farmers' access to bank credit and to increase productivity.[29] Other components, namely the creation of technical expertise in irrigation, determined the success of PROMOVALE in attaining diffusion of irrigation among both large and small farmers, for instance allowing the customization of irrigation projects.

The most successful components were river regularization, rural electrification, and small scale irrigation.[30] In 1981, PROMOVALE obtained funding from PROVARZEAS for its irrigation component. Shortly, PROVARZEAS-funded irrigation became the most important and successful component of PROMOVALE. Throughout the text, I discuss PROVARZEAS every time its characteristics explain the performance of PROMOVALE as well. I refer to PROMOVALE only when the state program differed from PROVARZEAS.

•Public projects assumed many different forms: large federal public projects, such as the DNOCS project in the municipality of Morada Nova (2,607 ha distributed in plots averaging 4.53 ha) on expropriated land, with flood irrigation; older collective irrigation projects, such as Quixaba, now discontinued. Public projects affected indirectly the diffusion of irrigated agriculture: for example, they demonstrated that new crops, such as irrigated rice, were profitable, enabled settlers to earn and save enough to leave the project and buy land in their villages of origin. These projects diffused knowledge about irrigation techniques.

•The irrigation kit program, started in 1989, distributed irrigation kits bought through a public procurement. The kits included a 7.5 CV motor, a pump, 7 sprinklers, and enough pipes to irrigate a square land plot of 3 ha. Farmers who owned less than 3 ha or that planned on planting less than 3 ha could get together to obtain the equipment. Landless farmers could get kits to work on the land they rented.[31] The program offered subsidized credit, to be repaid in cash or in kind (2 sacks of beans). However, there was no enforcement of repayment, since the state water agency, responsible for project implementation, lacked staff for exacting the payments, and BEC (Ceará State Bank) lacked an incentive, having obtained a full guarantee from the state.

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[29] Todaro 1981 shows that tenure dramatically increases small farmers' productivity over the productivity of farmers who do not have tenure.

[30] Estado do Ceará 1984, and interviews.

[31] Large farmers used this possibility to obtain multiple kits under their tenants' names.

In the next section, I show which characters of these public interventions contributed to their success in diffusing irrigation. In the fourth chapter, I deal with the mechanisms that facilitated small farmers' access to irrigation.

3. What determines success in irrigation diffusion

In the Lower Jaguaribe Valley some irrigation programs were more successful than others, adapted to local conditions better, and were able to introduce needed inputs better than others. In this section, I examine what determined success in irrigation programs: 1) programs that did not aim at the best possible technology but rather at giving farmers flexibility in switching from a crop to another did better than programs promoting advanced techniques that tied the farmers to one or few crops. 2) Programs that allowed for a customization of the irrigation projects to physical conditions of the field had better results, in terms of adoption and duration of the equipment, than programs that promoted a standard project design. 3) Finally, management techniques and workers motivation played a fundamental role in ensuring that public administrations efficiently performed such difficult tasks as project design and extension activities.

Project Design: best technical option vs what farmers really want

Policy makers decry the low technological level of irrigation in the Northeast.[32] Extension agents and private consultants complain about the farmers' low technological level, such as flood irrigation, shallow tubewells, earthen ditches, less watering than the agricultural manuals and the research centers recommend. They contrast it with the techniques they have studied or seen abroad, in Southern Brazil, or in the land of large agricultural entrepreneurs--drip, micro-drip, sprinklers, scientific determination of the quantity of water, irrigation, and fertilizer plants receive. Critics argue that farmers' simple techniques a) waste water and b) yield a lower productivity than more advanced technologies would allow. They blame the lack of adoption of more advanced technologies on farmers' lack of capital and knowledge, on their risk-aversion, and on crop price instability.

Water saving techniques

Indeed, few farmers adopt water-saving techniques such as drip and micro-drip in the lower Jaguaribe Valley because these techniques are expensive, water is available year-round, and subsidized electric power prices lower the cost of pumping water.[33] Drip and micro-drip require large initial investments, for example in hoses, and are only appropriate

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[32] Data from the State Water Agency.

[33] After the mid 1980s, the electric company discontinued the electric power subsidy for irrigation. However, prices of electric power for rural consumption are lower than the prices for urban consumption. Electric company officials state that the structure of prices is such that urban consumers cross-subsidy rural consumers.

for some crops, e.g., cantaloupes. Small farmers, instead, use inexpensive traditional techniques to reduce use of water in their fields, and thus lower electric power costs. For instance, small farmers who grow bananas water only once a week instead than twice a week as the extension agents suggest. To keep the moisture in the soil, small farmers reduce water evaporation by covering the earthen ditches and the soil with banana leaves.[34] According to the extension agents, these practices drastically reduce the dimensions of the fruit, while farmers say that the difference is insignificant. Farmers are less likely to pay much attention to differences in dimension of the fruit because, when they sell the bananas farmers measure them by number, not by weight. Dimension, then, is only relevant to determine the appearance of the fruit--i.e., its quality. Fruit quality is not important for small farmers who sell on the less demanding local markets (Fortaleza, for instance) rather than on the export markets.

Yield increasing techniques: General-purpose Equipment vs. Advanced Dedicated Equipment

The experience in the lower Jaguaribe Valley shows that, instead of advanced irrigation techniques and equipment that maximize the productivity of only one or few crops, farmers, and especially small farmers, need irrigation equipment and techniques that they can rapidly adapt to new crops. This particularly holds for farmers living in precarious climatic conditions and facing highly variable market demand. Therefore, programs, such as the kit program, that promoted dedicated equipment such as sprinklers, failed. Programs spreading general-purpose equipment, such as flood irrigation, achieved success in terms of farmers' permanent adoption of irrigated agriculture.

In the Lower Jaguaribe Valley, an irrigation program that promoted the adoption of sprinklers was not successful. The beneficiaries used the kits, composed of a 7.5 CV motor, a pump, 7 sprinklers, and enough pipes to irrigate a square land plot of 3 ha, only for a short time, because motors broke down more easily than the ones that the farmers already used. [35] However, the kit program had carefully sought to suit farmers' needs: for example, farmers could choose whether to repay their loans in kind or cash, renters could be beneficiaries of the program, and the bank involved received an over-the-board state guarantee to investment and operation loans.[36]

PROMOVALE, an irrigation program promoting small scale irrigation adaptable to different crops--motors as small as 15 CV for extracting water from the river, pumps,

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[34] Magalhães and Sousa 1995 state that Northeastern research centers fail to research water-saving techniques and varieties.

[35] Five beneficiaries (out of 412 in four municipalities) returned the equipment.

construction of wells, construction of cement canals or of earthen ditches--succeeded in diffusing irrigation equipment that farmers used for a long time. Both large and small farmers I interviewed in the summer of 1995 stated that they were still using the equipment they bought with the loans from the PROMOVALE program 12 to 15 years before--of course they had mended the motors several times, re-dug the earthen ditches, maintained the cement canals, drilled new wells when iron oxide had clogged the old ones,[37] and deepened wells when droughts lowered the water table.

Two factors explain the success of PROMOVALE and the failure of the kit program. First, the technology promoted by PROMOVALE entailed general-purpose equipment, that allowed farmers to grow a wide array of crops, while the kits were solely suited to irrigate beans. Second, while the kit program imposed the same standard design on all end users, PROMOVALE irrigation projects were customized to the physical characteristics of the individual farmer's land plot, such as the water source, the land slope, and the plot shape. I deal with the latter topic in the next section.

The sprinklers of the irrigation kit program permitted to grow only a small array of crops, namely beans, while PROMOVALE promoted flood irrigation, adaptable to a larger range of crops: not only beans, but also fruit and irrigated rice. Farmers in the lower Jaguaribe Valley, as in the rest of semi-arid Northeast, instead, need to use equipment that they can adapt to different crops, because they practice inter-cropping and devote parts of their fields to different crops. They diversify their crops to cope with the typical agricultural risks: unpredictability of weather, possible water shortages in the semi-arid area, variability in provision of inputs, and changes in relative crop prices.[38] The kit program, indeed, attempted at partially accommodating farmers' need to spatially diversify production by growing different crops on fractions of their fields or on altogether separated fields. The small dimension of the kit, able to irrigate only 3 ha, allowed farmers to devote only a portion of their fields to irrigated beans, while growing other crops on the reminder of the fields. Even thus, though, the irrigation kits were not suitable for intercropping. Intercropping is particularly important in the case of perennial crops such as bananas and guavas: the annual crops interplanted provide the farmers with income in the period before the bananas trees starts to yield.

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[36] Even the very state officials who implemented it in the lower Jaguaribe office of the state water agency, consider the kit program unsuccessful and state that it compares unfavorably with PROMOVALE.

[37] In some areas in the Jaguaribe Valley iron oxide clogs the small holes in the cement or plastic lining of the shallow tube wells. When the internal lining of the well is made of inexpensive, locally produced cement pipes, there is no solution but to dig a new well. On the contrary, when the internal lining is made of plastic pipe, farmers can extract the old pipe and substitute it with a new pipe.

[38] Mourshed 19969

Moreover, farmers do not only need to diversify their crops spatially. They also face instability in markets and in environmental conditions over time. They need to switch from a crop to another when an environmental crisis, such as plant diseases or floods, arises and when relative prices of crops change. In these conditions, dedicated, crop-specific equipment is less useful to farmers than flexible equipment, no matter how much the dedicated equipment can improve yields: a change in the environment can make that crop totally unprofitable or not viable. As a consequence, farmers need irrigation equipment that they can adapt to different crops over time: rather than sophisticated but crop-specific technologies such as sprinklers, farmers must use simple but adaptable irrigation techniques.

Project Design: Customized vs Standard Irrigation Projects

A different reason for success of irrigation programs is customization of irrigation projects--i.e., adaptation of the pump, motor, and distribution system to the physical conditions of the specific field of the end-user, such as land slope, plot shape, and type, depth, and capacity of the water source. Both general-purpose (i.e., flood irrigation) and dedicated equipment (sprinklers) can be adapted to the physical conditions of the fields in a customized project, or provided to the farmers with a standard project design.

In the lower Jaguaribe Valley, programs had better chances to succeed when they adapted the projects to the individual fields, and failed when they imposed a standard motor and pump size. When the project design did not suit the shape and slope of the plot and the height of the water table, the motor underwent more strain than it was built for. Strain on the motor, in turn, produced more frequent motor break-downs, and raised the costs of motor maintenance.

In the lower Jaguaribe Valley, the kit program standard project design made the irrigation kits inappropriate to the characteristics of individual land plots, to the point that farmers discontinued the use of the equipment. The irrigation kits were designed for 3 ha square fields, while in lower Jaguaribe land plots are long (up to 1.5 km.) and narrow (in some cases as narrow as 40 m); therefore, motors had to pump pressurized water to longer distances than it had been designed for. This imposed strain on the kits motors, and therefore caused more frequent motor failures than in the customized irrigation projects provided by PROMOVALE.[39]

There are different interpretations for the bad performance of the irrigation kit motors. Farmers blamed the more frequent motor break-downs on the worse quality of the

[39] Burn-outs are not the end of an electric motor's life in lower Jaguaribe. In the towns there are artisans that are perfectly willing and able to reconstruct the wiring of electric motors.

equipment, bought through a public bid, in comparison with the equipment that they could have bought autonomously from the local dealers. Conversely, state officials blamed farmers' failure and inability to properly operate and maintain the motors for their poor performance. While improper operation and maintenance did not cause major problems in flood irrigation, that required lower water pressure than sprinkler systems, they disrupted motors used for sprinkler irrigation.

Rather than imposing a pre-determined technical package like the kit program, PROMOVALE provided farmers with customized irrigation systems based on flood irrigation and the use of small scale equipment. EMATERCE extension agents, trained in irrigation in the framework of PROMOVALE, designed customized irrigation projects for the farmers, taking into account factors such as the microclimate, the typical shape of the fields, and water and energy sources.

Customization of irrigation projects is expensive: it requires the intervention of private or public sector consultants who have a specific expertise in irrigation. However, this is standard procedure for private irrigation: farmers either ask for the assistance of professionals and extension agents or have the equipment dealers design an irrigation system for them. On the basis of the projects, farmers bought irrigation equipment from local shops. They financed these purchases with the credit the program helped them to get from the public banks.

Customization of myriad of small-, medium-, and large-scale irrigation projects dispersed in peripheral rural areas is a bureaucratic nightmare. The necessary expertise may or may not be already present in the area.[40] More importantly, program managers need to make sure that, first, field-level workers, such as the extension agents, are really performing their job, and, second, that they are diffusing a type of irrigation both congruent with the central agency specifications and adapted to local condition. Since extension agents perform their job in isolated and dispersed areas, these are difficult tasks for the town-based extension supervisor. In the next section, I deal with the way PROMOVALE coped with these problems.

A Committed Bureaucracy

PROMOVALE at the state level, like PROVARZEAS at the federal level, worked hard to create workers' commitment for a specific project--the diffusion of irrigation in the wet lowlands of Brazil--and for a limited time--the federal program was originally scheduled to

[40] Irrigation project design is not exceedingly complex technically. Trained and experience professionals use coefficient tables and manuals.

last 10 years.[41] Moreover, in the case of the extension agents, PROVARZEAS dealt with workers it "borrowed" from other agencies, the state EMATERs.[42] These agencies had their autonomous culture and objectives, e.g., in the Northeast, fighting the boll-weevil and improving rainfed crops.

Federal top managers and technicians, state professionals, and extension workers knocked themselves out. They developed simple and inexpensive irrigation and drainage techniques and equipment, adapted them to local conditions, diffused information about irrigated agriculture among farmers, designed individual irrigation projects, and helped farmers finance them through bank loans.

Rather, PROVARZEAS federal top management made an effort to create a committed bureaucracy at the federal, state, and field level through the following strategies: a bond-creating and rigorous training system and a strict selection, site visits by state and national managers, informal and friendly personal interactions, the charisma and aura of technical ability of its top technicians, and the prestige the program enjoyed for being based on a technical and professional culture, rather than on political motives.

In addition, program managers widely publicized the program, both at a national level and in the valleys where they intervened, using instruments that could easily reach the farmers, for instance television series or celebrations in the field. This publicity aimed at creating expectations among the farmers that irrigation would have changed their life: the slogan of the program was "one hectare is worth ten".

b) Training

PROVARZEAS managers observed that in flood plains, where the potentiality for irrigation is maximum because of water availability, EMATER lacked agents specialized in

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[41] Throughout this section, I focus on PROVARZEAS and the way it solved the problem of motivating workers. PROMOVALE used PROVARZEAS resources, network, and strategies to motivate its workers.

[42] PROVARZEAS contracted agents from the state extension agencies, EMATERs, and paid the salaries of the extension agents it "borrowed". Therefore, PROVARZEAS managers thought, EMATER offices would have offered their best paid agents, to save their salaries, and thus free financial resources. PROVARZEAS managers' assumption was that the best paid extension agents were also the most skilled and motivated. In exchange for paying the salaries and offering training, PROVARZEAS managers expected that the extension agents contracted would work exclusively for the program. In the Jaguaribe Valley, though, this did not happen: the distinction between the tasks of the extension agents contracted out and of the others remained blurred. All extension agents continued to perform all tasks, just giving priority to the design of the irrigation projects and the diffusion of information on irrigated crops such as bananas. The blurring originated because PROVARZEAS paid the extension agents' salaries to the EMATERCE office budget, rather than directly to the agents. Therefore, EMATERCE used this funding (and the other resources, such as cars, that PROVARZEAS provided) as additional resources to finance the general operation of the office, rather than solely for the extension agents it contracted out to PROVARZEAS.

irrigation, and particularly in the engineering aspects of irrigated agriculture.[43] PROVARZEAS then 1) required that the state EMATERs deploy their extension agents specialized in irrigated agriculture in the offices of the municipalities in the targeted areas, 2) tried to attract the best and most motivated extension agents to work exclusively for the program, 3) offered training opportunities in irrigated agriculture, and particularly in irrigation project design, to the extension agents it "borrowed". The training system offered extension agents short-term training in irrigated agriculture, such as internships and courses in different parts of Brazil. It also provided top state managers and technicians formal graduate education in irrigated agriculture both within and outside Brazil. In this way, PROVARZEAS created the competencies necessary for making the program work. For example, top state technicians earned the skills they needed to adapt drainage and irrigation techniques to the conditions of the project river valleys in their states. Extension agents learned how to design the customized irrigation projects.

More importantly, the training system socialized the workers, and created a sense of commitment and of sharing the objectives of the program. Like the training in the mandarin model of public administration, PROVARZEAS training creating a sense of belonging to a group that shares the same competencies through a background of common experience. It was successful at creating bonds--from which eventually networking evolved--even if it could not provide the same long and tough training the mandarin model uses to socialize elite bureaucrats.

In the training courses, extension agents from different regions in Brazil compared the diverse problems, and related solutions, the program encountered in different environments: the wet lowlands of the South, the savannas in the Center-West, the poverty-stricken alluvial valleys of the Northeast. In this way, the training system provided a nation-wide arena for the comparison of experiences in a narrow field, namely drainage and irrigation of river valleys and wet river lowlands all over Brazil. Moreover, PROVARZEAS shows how a training system can embed information-sharing in a program institutional design. Finally, by creating long-term personal bonds, the training system created a long-lasting network of extension agents and irrigation technicians that continue to interact to date.

The training system may appear too large an effort for the purpose of making a time-limited program operate well. However, it had, at least in the lower Jaguaribe Valley, long-term results: it created a permanent expertise in irrigation in the public sector and, in the long term, in the private sector as well.

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[43] State Water Agency.

c) Site visits

Even though PROMOVALE has been over for more than a decade now, the people that worked in it still interact and network: they exchange information about job or career opportunities in both the public and the private sector; Ceará PROMOVALE former officials network with the officials of the national PROVARZEAS and of the state programs in other areas in Brazil.[44] A system of site visits by the top-level managers to the small towns and villages where the program was implementing drainage and irrigation projects helped build informal and close relation between the top managers, the state managers, and the field-level workers. These close relations, together with the charisma of the leader of the program, and the aura of technical ability of the top federal technicians, were a powerful element in creating field-workers' motivation. To date, top managers remember the most motivated and best workers in the field, who, in turn, remember them.

Moreover, site visits provided state and federal managers with the possibility of informally learning whether the field-workers were performing their job. Obviously, the creation of a network was a side effect of the site visits, rather than its main purpose. Rather, site visits aimed at giving the city-based federal and state technicians information about farmers' needs and the characteristics of the areas where the program was implemented. They were, therefore, key in the process of adaptation of drainage and irrigation techniques to field conditions.

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[44] The very way I got my contacts in Brasilia and in the field is telling of the way the network works. I obtained the names of the promoters of PROVARZEAS from PROMOVALE people in Fortaleza, who made the necessary phone calls and arranged the contacts. In Brasilia, the national level officials gave me names of people I could contact in the communities. In general, everybody was aware of the whereabouts of the other people in the programs.

4. Reaching small farmers: inadvertently creating the conditions for small farmers' autonomous action

So far, I have dealt with the elements of success of programs, but not with how programs managed to help small farmers acquire irrigation. The elements that made the programs successful, i.e., workers' commitment, a flexible project design, and customization of the projects, also helped them reach small farmers. For instance, the small scale, simple, and general-purpose project design suited well small farmers' needs. That small farmers need small scale equipment to acquire individual irrigation comes as no surprise. What is surprising, instead, is that programs successfully promoted this simple and hardly glamorous technological option in an environment that favors large scale projects and advanced technical options.

Irrigation programs in the lower Jaguaribe Valley reached small farmers inadvertently, even though targeting small farmers was not their primary objective, and indirectly, when arrangements meant to solve other problems created an environment conducive to small farmers' autonomous action. Neither PROMOVALE, or its federal counterpart PROVARZEAS, had targeting small farmers as a primary objective. Rather, PROVARZEAS aimed at diffusing individual irrigation in flood plains, in particular to increase the national production of grains.[45] Yet, it did particularly reach small farmers.[46] The political promoter of PROMOVALE had the objective of demonstrating that individual private irrigation worked better than large public projects at 1) increasing agricultural productivity in the valley for 2) large, medium, and small farmers alike. Reaching small farmers was not an end in itself. Rather, it served the purpose of opposing the large public irrigation projects of DNOCS, that targeted specifically small farmers and the landless.

Apart from political motives, the politician that first supported the program, Manuel de Castro, had a personal reason for opposing large irrigation projects: DNOCS had expropriated his family's land to build the large irrigation project in Morada Nova. This personal motive undoubtedly played a part in the high political priority that PROMOVALE enjoyed while Castro was vice-governor and then governor of Ceará. However, this was not an idiosyncratic case in which political pressure by the governor of the state made a program work. Rather, widespread fear of further expropriations motivated large farmers

[45] Ministério da Agricultura 1988.

[46] WB 1990. However, this document probably uses a definition of small farmers that includes farmers that in this paper would be defined medium.

and local politicians to let small farmers access irrigation programs and the rural electrification process.[47]

Often, instead, irrigation programs fail to reach small and very small farmers even when they target them. The failure in reaching small farmers has many causes: a) large and medium farmers appropriate the rationed private-good-type resources that irrigation programs offer, such as equipment, extension services, and subsidized credit.[48] They therefore exclude small farmers from accessing these resources.[49] Unlike small farmers, large farmers can spend time applying for loans or grants and traveling to the municipal seats or even the state capital. Large farmers can use their political influence, knowledge of laws and state programs, and access to institutions to apply for bank loans before anybody else and to get preferential access. b) Repair services and small scale equipment, such as 3 or 7 CV motors, are not available in rural towns; c) small farmers lack knowledge of irrigated agriculture; and d) electrification agencies fail to connect small farmers to the electric network; as a result, small farmers cannot pay for the more costly diesel motors and therefore do not manage to access irrigation. Small farmers find it difficult to apply for getting the connection to the electric network, such as the need to forego days of work and bear expenses to go to town. Moreover, small farmers cannot afford the connections or are afraid of not being able to pay for the electric power after they are connected. Often, the electric companies design the lines to serve few large landowners. In so doing, they exploit economies of scale in the construction of the lines, and forego the high costs of connecting many dispersed rural consumers whose low levels of consumption do not provide adequate returns.

Most small farmers paid for their equipment with their own money, either mobilizing their savings or obtaining credit from middlemen and equipment dealers. My interviewees stated that they managed to pay back the installments to the equipment dealers with the first two harvests and their savings.[50] The literature has long shown that both savings and

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[47] Sampaio 1974 states that land expropriations affected small farmers and landless peasants as well as large landowners. The number of small and landless farmers that had to relocate in consequence of the implementation of a large irrigation projects was larger than the number of the new settlers. The expropriations impoverished dislocated farmers.

[48] WB 1990: 5.

[49] Tendler 1993:1575

[50] Small farmers invest their savings in livestock, to keep them in a productive and easily liquid form. They report to have bought a cow and having later sold the same cow and its calf to pay the installment back.

informal financial markets indeed exist in rural areas among small farmers, awaiting favorable market conditions.[51]

In this section, I deal with the conditions that allowed irrigation programs to reach small farmers, directly or indirectly: 1) public intervention spurred a small-scale, simple technology that suited large and small farmers' needs; 2) in so doing, they created a demand for small scale equipment; 3) as a result, private dealers started selling small equipment locally further facilitating autonomous investment by small and very small farmers; 4) to a certain extent, large farmers facilitated, rather than precluding, small farmers' participation to the benefits of the programs, namely irrigation.

A simple technology and its indirect effects

Small farmers managed to find low cost, small scale irrigation equipment suited to their needs in the towns in the Lower Jaguaribe Valley, as an indirect effect of PROMOVALE, years after it started. As I argue in Chapter 3, PROMOVALE offered subsidized credit and project design for small scale, general-purpose technology--for example labor-intensive, animal-traction machinery for land systematization, and low-lift or gravity systems for irrigation. The program could count on committed and trained extension agents who were able to adapt the project design to the necessities and financial capabilities of its clients. For instance, extension agents designed cement canals for large farmers, but recommended inexpensive earthen ditches, lined with plastic, to smaller farmers.

The creation of a demand for small scale irrigation equipment was possible because farmers bought their equipment from the dealer in the Valley. Under other programs, namely the irrigation kits program, the government bought irrigation equipment with a centralized state-wide bid and then distributed it to farmers. Therefore, no local demand gradually grew, and no local backward linkages could develop in program areas. Equipment dealers and manufacturers did not receive market signals to set offices, shops, and repair services in rural areas and in peripheral towns. Centralized purchase of equipment, therefore, failing to encourage the development of a supply network in the interior towns, made it more difficult for poorer farmers to acquire irrigation equipment.

From 1981 to 1985, PROMOVALE financed and spurred a sustained demand for small scale irrigation equipment, such as pumps, triphasic motors (maximum dimension 15 CV), cement or plastic pipes, produced in Fortaleza or in the South and South-east of

[51] Hirschman 1958 shows that hidden resources, such as capital, exist in developing countries. He also identifies conditions under which they are mobilized. Timmer 1995 further develops this point, with a focus on small farmers.

Brazil. Usually, each project entailed one motor, one pump, and equipment for the cement canals and the wells. In few cases, however, the projects included multiple motors and pumps, because it provided for more than one water point, or for more than one motor and pump in the same water source. Moreover, medium and large farmers often bought additional investments on their own, at times few months or years after the first PROMOVALE projects.

The creation of a local demand for equipment relied on small and large farmers both using similar techniques and small scale equipment--the range of motors varying from 2.5 CV to 15 CV. In my definition of large farmers I do not include very large agricultural entrepreneurs.[52] Rather, the larger farmers I deal with (defined as farming more than 20 ha of irrigated land) have much in common with small farmers. They grow rice, beans, fruit such as bananas, guavas, acerolas, or vegetables such as peppers on about 40 or 50 ha of (rented or owned) irrigated land, and raise cattle on non-irrigated land. Some of the crops they grow are the same that the small farmers grow: rice, beans, bananas.

Even the large farmers keep the size of their equipment small, and simply multiply the water sources and the equipment to irrigate their land. Extracting water from many water points with small motors is normally less efficient technically than using one large motor, in terms of water extracted per energy unit. However, using many small motors is more efficient for large farmers for the following reasons.[53] First, small scale equipment permitted large farmers to invest in irrigation equipment incrementally over time, thus diminishing risk. Therefore, large farmers acquired their irrigation equipment sequentially. Second, they own or rent separate land plots in different areas of the valley and the surrounding sertão, to diversify risk and to be able to grow different crops on appropriate land.[54] Third, they divide even their contiguous fields among many crops and practice intercropping of annual crops with perennial crops. Fourth, in the lower Jaguaribe Valley, plots have the shape of long strips with one end on the river bank and the other on the road. A single irrigation system with a single water source on a plot that may be as long as 1.5 km and only 40 m wide would require long distribution canals and taking much space. Therefore, large farmers use wells as additional water sources. Fifth, farmers and project designers preferred to use two, three, or even four smaller motors instead of a single larger

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[52] These entrepreneurs produce fruit such as cantaloupes on large (more than 100ha) plots irrigated with advanced technologies such as drip and with intensive and scientifically-determined use of inputs.

[53] For example, one large PROMOVALE beneficiary grew rice in a land plot divided in three strips, each of them in turn divided in three square rice paddies. He extracted water from the river with three 15 CV motors, and distributed it in the fields with cement canals.

[54] Tendler 1993 describes how the similarity between small and large farmers' cropping patterns (all of them adopted intercropping techniques) facilitated the development and diffusion of agricultural innovations appropriate to small farmers.

one to ensure against equipment failure at a crucial time in the watering cycle. This makes sense, given that in the beginning of the 1980s, when PROMOVALE diffused irrigation in the Lower Jaguaribe Valley, brown-outs and black-outs were frequent and damaged motors.

Initially, farmers had to buy their equipment in Fortaleza or, locally, at the state agency CODAGRO (state agency for the sale of agricultural implements). At the same time, in the towns of the Valley, dealers of durable consumer goods or agricultural implements started selling irrigation equipment. Once manufacturers of irrigation equipment, particularly Ceará-based pump producer King, identified that a demand for small scale equipment was growing in the lower Jaguaribe, they started to enter the new market.

In the villages, moreover, backward linkages prompted small artisans to produce cement goods such as pipes for canals or for the internal lining of shallow tubewells and cement poles for the minor connection electric lines between the transformer and the location of the motor. In the beginning, farmers had to go for repair services of motors and pumps to Fortaleza, 160 km from Limoeiro do Norte. Local extension agents helped create a local supply of simple, first-aid motor and pump repair services in the commentates: they arranged for King to provide short (four-day) training courses in basic maintenance and repair to village members. The manufacturer accepted because it felt that providing for local repair service could increase the demand for its products: farmers would have felt confident that they could fix their equipment, and therefore would have been more likely to buy it.[55]

Finally, this gradually expanding demand for equipment and repair services also helped the small but thriving metal-working sector, previously dealing mainly with automobile parts in the town of Tabuleiro do Norte. The small metalworking shops in Tabuleiro have traditionally been building specialized parts for cars--rich people from Fortaleza have spare parts for their cars made in Tabuleiro. They have also been producing and repairing windmills. During the 1980s, they started to produce small pumps for irrigation.

A Prestigious Program spurs a Simple Technology

PROMOVALE diffused low-cost, small-scale equipment and simple techniques, building on farmers' traditional knowledge of irrigated agriculture. As one of the former top state PROMOVALE managers proudly told me "the techniques we promoted were not simple, they were rudimentary." PROMOVALE showed a consistently lower cost per hectare of irrigation implementation than usual in the Northeast: in 1983, for example, the

[55] King faced the risk of enlarging the market for its competitors as well. However, this risk was somewhat limited because the irrigation projects could include the specification of the brand of the equipment.

average cost of irrigation per hectare in Ceará was US$ 910 per hectare, decidedly below the cost of private irrigation in the Northeast,[56] and even below the implementation costs per hectare of public projects.[57] This orientation toward small scale simple techniques is unusual. More unusually yet, these techniques were prestigious enough for extension agents to diffuse them.

Unlikely convergences of interests: interactions between large and small farmers.

The necessity of targeting originates from the idea that the interest of large and small farmers necessarily clash. The greater the amount of benefits large farmers receive, the lower the amount of benefits small farmers can obtain. Under certain conditions, however, the interests of small and large farmers overlap e.g., in fights against pests.[58] The story of diffusion of irrigation among small farmers in the lower Jaguaribe Valley shows that in this particular case there was no clear-cut opposition of interest. Some measures that benefited primarily large farmers also positively affected small farmers, e.g., large farmers' demand for equipment ended up making the equipment locally available for small farmers. In this peculiar case, substantial similarities in some crops and in plot size between small and large farmers blurred the opposition of interests. The similarities between the small and the large farmers do not imply, however, that they share the same interests or that there are no perceived social differences within the villages. On the contrary, larger farmers constitute the village elite, and are often the village political leaders and largest employers. In the villages, clientelistic and patronage relations between large and small farmers appear likely to jeopardize any possible development for the small farmers and the landless peasants that get caught in these power relations. Emancipation is all the more difficult because moral obligations, gratitude, and social conventions intermix with exploitation. Surprisingly, though, in some instances these very clientelistic relations helped, in the long run, small farmers to partially free themselves from their dependence on the large farmer.

The supply of credit and extension services was indeed limited in the short term: appropriation by large farmers could reduce small farmers' access to these services. However, credit or extension services were not the major obstacles to the diffusion of irrigation among small farmers. For instance, small and very small farmers seldom had access to bank credit, but could obtain credit from middlemen and from the equipment dealers.

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[56] WB 1990: 8

[57] Costs include land systemization, building of the earthen ditches or the cement canals, digging of wells, purchase and implementation of the equipment, and technical assistance.

Rather, small farmers needed local availability of small scale equipment, widespread knowledge of irrigated agriculture, and electric connections. Instead of being diffused by the extension agents among small and very small farmers, knowledge about irrigated agriculture trickled down to small farmers mainly through the social networks in which the small farmers are embedded: they learned from the large farmers for whom they worked part-time, from their neighbors, and through the clientelistic and paternalistic relations between the large and the small farmers.

The interests of large and small farmers converged. For example, when the rural electrification process started in lower Jaguaribe, some larger farmers helped the small farmers get electric connections, by offering rides to town for the paperwork, or eliciting participation in meetings. Large farmers helped the small ones both as part of their social obligations and as a way to increase demand for electric connections and thus speed up the electrification process.

Once they obtained the electric connection, small farmers started investing in their own electric irrigation equipment. Over time, small farmers could increase their income, farm their field year-round, and thus decrease their need for asking for off-season jobs from the large farmer. This might weaken the clientelistic relation between the small and the large farmers over time, but not make them disappear: small farmers feel gratitude for the large powerful farmer who helped them.[59]

Finally, in the case of rural electrification, local politicians tried to include small farmers in the process, so as to obtain political clout. Encouraged by Manuel de Castro, the political promoter of PROMOVALE, local politicians that either were mayors in the lower Jaguaribe Valley or wanted to become mayors tried to obtain political support and popularity acting as promoters of rural electrification. They helped put pressure on the rural electrification company by collecting signatures and data from the farmers that wanted a connection to the electric line. The information collected regarded the size of the desired connection, the size of the land, and where the plots were located. Even though the signature lists did not have legal value, they showed the electrification cooperative that demand for electrical connections indeed existed, the amount of this demand, and the location of the potential customers.

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[58] Tendler 1993

[59] Political and social life in the villages is organized around large farmers, who employ and "protect" small farmers and landless peasants, building clientelistic relations with them. The main base for the power of large farmers is their ability of hiring small and very small farmers. By hiring themselves out, small farmers can complement the meager income they obtain from their fields and make a living in the dry months or during droughts.

5. Conclusions

The diffusion of irrigation in the lower Jaguaribe Valley teaches lessons about how to achieve success in irrigation programs. Particularly, it shows how programs spurring individual irrigation can, directly or indirectly, benefit small farmers.

Irrigation programs tend to introduce equipment and techniques that represent the optimal technical choice for production of a single or a small array of crops, namely sprinklers vs low-lift or gravity irrigation. Yet, farmers, especially small farmers, are not likely to use dedicated equipment and techniques, regardless of the increases in yields they can produce, if they face high risks or fear changes in long-term (as opposed to seasonal) prices of crops. Therefore, particularly when trying to benefit small farmers who cannot cushion market shocks through their savings, irrigation programs should favor general-purpose, small scale equipment.

Focusing on a simple, rather than an advanced, technology, can be administratively difficult. Policy makers prefer to sponsor, and professionals want to work in, programs spurring advanced technologies, rather than promoting traditional methods. Irrigation programs can make simple techniques attractive by motivating the professionals to diffuse simple techniques, by providing training, and by attaching the development of simple techniques to widely respected technicians and researchers, and by advertising the success of the program.

The example of the Lower Jaguaribe Valley shows how programs promoting small scale irrigation equipment can reach the poor indirectly. It shows how to elicit: a) a local private supply of small scale irrigation equipment and repair services; b) a long-lasting supply of expertise in irrigated agriculture and irrigation project design both in the extension agency and in the private sector. In this way, in addition to facilitate diffusion of irrigation among small farmers, programs can also increase non-agricultural income opportunities for people in rural areas, and both contribute to and benefit from industrialization processes in peripheral towns, as it happened in the case of the pre-existing metal-working sector in the small town of Tabuleiro.

PROMOVALE obtained good results because it adapted its technology to a) the local environment, market, landownership, and social structure of the project areas, b) the conditions of the individual field, and c) the preexisting traditional technical knowledge of farmers. Other programs, in contrast, namely the kit program, imposed a standard project design and dedicated equipment that tied the irrigation equipment to a narrow range of crops. This made the irrigation programs inappropriate to the farming conditions prevalent in all or part of the target area.

The adaptation of project design to local and individual conditions constitutes a bureaucratic nightmare. It requires the coordinated work of an army of researchers in state or regional offices and extension agents dispersed in peripheral rural areas. The experience of the Lower Jaguaribe Valley points out that a nation-wide program addressing a single problem--irrigation of flood plains--can provide a better institutional framework for adaptation than multi-purpose programs aimed at correcting regional imbalances. In the former case, researchers and extension agents can concentrate on just one task, and therefore achieve better results. In addition, program managers and technicians anticipate the need to deal with very different micro-regions in different areas in the country. They are therefore in a better position to adapt their action to the specific conditions of each target area. Multi-purpose regional program, instead, usually target a whole region or a state within a region. In the case of the Brazilian Northeast, this means targeting a region much larger than European countries such as Spain. Even if the targeted area comprises only a group of municipalities within a state, though, it can present such diverse areas as semi-arid zones, alluvial valleys, and highlands. Adaptation of many different types of projects across an internally diverse area is a complex task, that can be made more complex by aggregated official data that do not account for internal diversities.

A nation-wide sectoral program providing a bond-creating training system creates an arena for researchers and extension agents to exchange information. In so doing, a sectoral program institutionalizes one of the determinants of success in dissemination of innovation: informal contacts and exchange of information among extension agents and researchers about a well defined problem in different settings.

In adapting a technical option to diverse concrete conditions, a program must make difficult choices about which existing elements to change, which new desirable elements to introduce, and which pre-existing elements to preserve. Pre-existing elements can constitute opportunities or obstacles: a highly fragmented land structure or traditionally shaped land plots may hinder the implementation of efficient large scale irrigation and construction of rational water distribution systems. At the same time, however, this "inefficient" landownership structure forces large and medium farmers to use small scale irrigation, thus facilitating small farmers' access to irrigation.

The interactions between large and small farmers can, occasionally, yield a positive outcome for the small farmers. In the lower Jaguaribe Valley, first, local politicians and large farmers supported an irrigation program, PROMOVALE, primarily because it served to demonstrate that large collective irrigation projects, targeting specifically and solely small farmers and landless peasants, were not as effective at spurring irrigated agriculture as individual irrigation. To achieve their objective, however, large farmers had to let small

farmers benefit from interventions such as rural electrification. Moreover, the indirect effects of public irrigation projects, such as demonstration of viability of irrigated crops, facilitated the diffusion of individual irrigation. Even when their collective arrangements failed, public projects left behind knowledge, networking, and physical capital on which farmers built to achieve individual irrigation on the formerly collective irrigation projects. Finally, in the large public projects, farmers managed to earn enough knowledge and money to relocate elsewhere when they so wished.

Third, even if there is indeed competition between large and small farmers for the benefits of the program, the situation can change over time. For example, by obtaining subsidized credit or extension services, large farmers do take them away from small farmers. By investing in equipment, however, large farmers can elicit a growing local supply for irrigation equipment. .

Cooperation and convergences of interests can arise even between large and small farmers. Under certain conditions, large farmers want small farmers to access programs, and even help them. Large farmers may need the demand pressure of the small farmers to make an administration work: in the case of rural electrification, a combination of political pressure and organized demand by large and farmers set the pace for the rural electrification cooperative.

The story of diffusion of irrigation in the Lower Jaguaribe Valley presents phenomena that could be explained as the effect of leadership and of personal political pressure. In the case of PROVARZEAS, the founder of the program is a charismatic leader. The enthusiasm of his former colleagues and field-level workers is so great that it is difficult to step back and analyze what he actually did. But when analyzing the program more closely, it appears clearly that the program worked well because it used strategies that can be replicated in other settings. For example, PROVARZEAS used training to a) build the necessary competencies to make the program work, b) give prestige to the simple techniques the program promoted, c) create a nation-wide arena for exchange of experiences.

In the case of the rural electrification, political pressure exerted by the state government appears to explain the performance of the electric company and the rural electrification cooperative in reaching small farmers. The way central and local politicians and large farmers acted, however, teaches lessons in exerting local pressure on electrification administration. In both cases, in sum, the role of a truly exceptional person or the political agenda of the state governor fade in the background in comparison with the institutional and political framework in which they operated.

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