Local water management and family agriculture in semi-arid Brazilian Northeast : limits and challenge

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Abstract:

In the Brazilian Northeast, a lack of water and unequal land distribution had maintained peasant families in a situation of dependence. The socio-economic impact of droughts had lead to successive state interventions assimilating irrigation to the modernisation of agriculture. Concentrating on large projects (big dams and large irrigation areas), which have generated a centralised water management but did not resolve the dependence problem. This paper analyses small holders' water management practice, strategies and alternatives, and in particular, innovation for productive use of superficial water. Adoption and adaptation problems of this kind of proposal show how technical change is linked to social and institutional transformations.

Résumé:

Au Nordeste du Brésil, la rareté de l'eau et la répartition foncière ont perpétué une situation de dépendance des agriculteurs familiaux. L'impact des sécheresses a suscité l'intervention des pouvoirs publics associant l'irrigation à la modernisation agricole. Celle-ci, concentrée autour de grands barrages et périmètres irrigués, a conduit à une centralisation de la gestion de l'eau sans parvenir à satisfaire les besoins de la population rurale. Le texte analyse diverses pratiques et stratégies de gestion de l'eau mise en oeuvre par les agriculteurs, en particulier les innovations en matière d'utilisation productive des eaux superficielles. Les problèmes d'adaptation de ces propositions montrent combien les changements techniques sont intimement liés aux changements sociaux et institutionnels.

Introduction

In the Brazilian semi-arid Northeast region, the "Sertão", lack of water and unequal land distribution had maintained peasant families in a situation of dependence. The socio-economic impact of droughts on one hand, and the assimilation of irrigation to the modernisation of agriculture, on the other one, had lead to successive state interventions. Concentrated on large projects (big dams and large irrigation areas), they have conducted to a centralised water management. As shows Molle[1], they have not resolved the peasants dependence problem and even they have not reached to valorise in an efficient way the water resources actually available. Hydra resource management depends of the relation between demand and offer of water. We first present the main elements of this relation and its evolution according to the hydra public policies in the region. This presentation unlighted small holder's water management practises and strategies, particularly speaking of productive use of water. In a second time we analyse some experiences of innovation and improvement of water management local system adapted by family agriculture.

Water management in the semi-arid Northeast

Water in the Brazilian Sertão

Water management in the rural semi-arid area integrates domestic and productive use (animals drinking, receding irrigation, lowlands agriculture and conventional irrigation). It depends first on climatic, geologic and hydrological factors. Rainfall, generally above 700 mm/year, presents a very irregular distribution. Evaporation is very high: annual ETP remains between 2,000 & 3,000 mm). Also, there are practically no perennial rivers, except the São Francisco and Parnaíba rivers. Hydrological conditions are marked by two contrasted geological situations. The sedimentary area corresponds to 40 % of the semi-arid zone surface. It presents some important underground water bodies of good quality for agricultural utilisation as well as for human consumption. But, these reserves, estimated to 400 milliards of m3, can only be accessed through deep drillings associated to powerful and expensive pumping systems (20.000 to 100.000 U$, according to the depth.

The extremely permeable soils are not feasible for dam building because of infiltration risks. To the contrary, in the crystalline area, underground waters are rare and generally saline. However, some razed and permeable soils favoured superficial flows and storage possibility with land dams locally called "*açudes*" (box 1). The agricultural occupation of the region had yet provoked important eco-systems degradation. Sustainable agriculture development implies an appropriate management of the "soil-water-vegetation" system as a whole, in order to limit water loss (evaporation, infiltration, flows) but also land degradation by the diverse forms of erosion erosion [2].

Some two million of families still go through long periods of difficulties of water supply and remain at the mercy of prolonged and intense and recurrent droughts. To reduce their socio-economical damages, a succession of big projects over against the droughts had been conduced by the public authorities since imperial period. Molle[1], shows the correlation, during the 20th Century, between drought periods and the federal investments via the National Department of Works over against the Droughts (DNOCS). These policies, marked by concentrated investments in big dams associated to vast irrigation schemes, had shown their limitations[3]. They lead to the centralisation of hydra resources where the users are scattered and the farming systems and situations in the rural area extremely diversified.
The priority for town and cattle supply lead to the construction of big dams and huge reservoirs, for flooding and the expropriation of fertile low lands areas, generally occupied by family agriculture. This centralisation also engenders elevated water transport costs through canals or water trucks. The same way as with public or private dams, the sadly famous "*caminhão-pipa*" (water trucks) constitute one of the main dominant tools for landlords (called "*fazendeiros*") and local politicians, because of the social and political negotiation of water distribution[4]. Traditional productive water management systems can be assimilated to the valorisation of lowlands developed since the Portuguese colonisation of the *Sertão*. Historically, the principal objective of these systems was to guarantee human and cattle consumption. The development of cropping systems using water from small land-dams and wells has always been secondary. It has appeared as an alternative with the construction of *açudes* allowing for the conserving of a reserve of water from one year to the other[5].

The main question of the *açudes* system comes from their distribution and from the problem of access to land and water for the small holders. From 1915 to 1967, more than 600 private *açudes* were built through the "*Regime de Cooperação*" (Co-operation Scheme). The Federal State financed the project studies and the equipment to built the dams; the peasant local communities provided the work force and the "*fazendeiro*" (the owner) the land. He was supposed, in compensation, to "*supply water for the neighbouring population according to their domestic needs*". If local populations' access to water was diversely tolerated by the main part of the landlords, many of them controlled the cattle drinking during dry periods. The access to the land bearing these "community dams" was practically always denied, even to the small holders' families that had contributed to their construction. Federal intervention until the seventies was mainly dedicated to the carrying out and financing, with public funds, the private dam construction initiated by the landlords. It has been materialised by an improvement of human and cattle supply under the control of the landlords also called "*colonels*".

With agriculture modernisation in the years 1970, the Federal State, supported by the World Bank, implanted important irrigation infrastructures associated to big dams. Public irrigation projects, principally concentrated in the São Francisco Valley and around the big dams occupy more than 100,000 ha for a potential irrigated area of 453,000 ha in the Northeast[6] more or less 5% of the total surface of Northeast semi-arid region (94,000,000 ha). The emphasis of the discourse associated to these projects is as much inflated as the volume of the investments. It illustrates a technocratic ideology founded on two certainties: (1) irrigation is the solution for regional economical development, (2) the State assuring the infrastructures, the rest will follow on ...This position explains the super-proportions of numerous infra-structures, their management difficulties, particularly by the small holders' organisations, and the sub-utilisation of diverse reservoirs and equipment.

This frame helps to identify to situations. Access to water in the sedimentary zone needs financial and technological resources, not readily accessible for family agriculture. In the crystalline zone, storage of superficial water is possible with reduced investments. But it depends narrowly on land access, held up by the unequal distribution.

The main water management systems of family agriculture

We can distinguish five types of water demand in the rural area: human consumption (drinking and cooking water), domestic consumption (body, clothe and dishes washing, etc.), animal consumption); small agro-industry units consumption (manioc and cassava mills, cheese fabrics) and, agriculture consumption. The satisfaction of these demands, marked by different needs such as quality, quantity and periodicity, depends on the volume and the characteristics of the water offered. But it varies also in the functioning of two factors: the type of catchment and storage infrastructures or equipment (river, dam, and well) and the regulation forms of access to water (legislation, norms and rules, conventions of use). We will only deal here with animals and agriculture consumption. This latter covers four farming systems: irrigated farming, receding irrigation farming, lowland agriculture without irrigation and rain fed agriculture.

Irrigated farming

Irrigated family farming is concentrated on the irrigation schemes associated to the big public *açudes* in the north Sertão and to hydroelectric dams' complexes along the São Francisco River. This model, because of its cost, has reduced its expansion. Most optimistic previsions for the implantation of new irrigated projects don't exceed 300000 ha[7].
We observe, on the one hand, a reduction of the irrigated surfaces and of the number of small holders called "*colonos",* around the big *açudes,* and, on the other hand, their substitution by farmers or business men in the public projects of the São Francisco Valley. This policy is justified by public authorities because of the economical weight of irrigated tropical fruits production in terms of currency supply, and, above all, because of a presumed superior efficiency of the business model. However, the production for exportation (mainly mango and grapes) is extremely concentrated in the pole of Petrolina-Juazeiro. Then, it is particularly reduced in the diverse irrigation projects of the region; especially those built to resettle small holders expropriated by the construction of hydroelectric complexes. The small holders who without any previous experience of irrigation have kept their businesses and are carrying on with small irrigated parcels of 2 or 5 ha, are those that could implant perennial crops (banana, coconuts, guava) or have converted to milk production with irrigated forage.

Receding irrigation farming

We can find references of receding irrigation practices, accompanying the water level retirement in the intermittent rivers of Seridó Valley in Rio Grande do Norte since 1823[8].

This practice was extended to the borders of the *açudes*, small or big ones, mainly for food crops of short growth cycle with strong root development: beans (*Vigna*), sweet potatoes (*Ipomea batata*), cucurbitaceas and forage grass, principally *Brachiaria and Echinochloa* species. This system has, during more than a century, assured the development of extensive cattle breeding systems the Serido region (Rio Grande do Norte and Paraíba). It is based on forage complementation during dry season cutting the Andrequicê grass *(Ichnanthus bambusiflora*). We observed the production of 30 to 60 t/ha of green matter for one cutting. The main problem is the protection of food crops and forage crops from the invasion of animal which is resolved by using fences.

Lowlands agriculture without irrigation

The challenge of the valorisation of the lowlands in the semi-arid Northeast is quite important, maybe more, than the conventional irrigation potential. Some 5% of the crystalline area (more or less 3.5 million ha) are covered by small alluvial deposits with a middle depth of 3 m, associated to phreatic water bodies. The main part of the region has saline underground waters of difficult access (weak flow drillings). It is precisely, around these alluvial zones inserted in the fends of crystalline base, that the populations of the *Sertão* has been progressively established. At first, it was in order to guarantee cattle drinking, then, families water supply, when the settlement became permanent and finally crops. There was first food crops: corn, beans and manioc, but also vegetables: sweet potatoes, *cucurbitacea*, then the semi-perennial crops (sugarcane, banana.) and at last fruit crops: coconut trees, papaya, mango trees and citrus. In a second step, lowlands were used for forage crops *(Panicum, pennisetum* and *Brachiaria* species grasses and legume fodder crops or trees as the *Algarroba (Prosopis* j*uliflora,* introduced from Peru) and a forage cactus called *"Palma" (Opuntia sp.*), introduced from Mexico).

Water management integrated to local farming systems generally combined the utilisation of three main kinds of infrastructures: the small and medium land-dams (*açude)*, the superficial alluvial wells or "*cacimbas*" and the traditional wells called "*poço amazonas*" or also "*cacimbão*". They can also be associated with other types of ready offers of water: small natural lagoons, springs and "*caldeirões*" (cauldrons). They are rocky outcrops, generally of granite, sometimes localised in the bed of intermittent rivers or dug by fire that constitute a kind of open water tank.

Box 1: **The land dam or *açude***

Introduced by the Portuguese who have known this technology since the Arabian occupation (*açude* comes from the word *al saad,* which means "dam" in Arab), the construction of the *açude* consist of damming an intermittent river or streamlets with a dike of land carried from the hydraulic basin and compacted manually or with a tractor. The dam is completed by an support-trench reducing infiltration under the dike and a outlet canal**,** generally cut in a lateral position. There exist different types of dams with diverse capacities according to their position in the watershed and to the importance of the dammed river (see classification below). Today, we count more than 75,000 small *açudes* in the Northeast. Their resistance to drought that is the period the dam will keep water, depends on:
- the filling up : depending on the size and area of the watershed, on the flows it can produce (according to the type of the soils) and, finally, on the local rainfall characteristics;
- the quantity of water taken off by evaporation (the deeper the dam is, the lesser is the evaporation), by infiltration or by consumption: irrigation, animals drinking and human supply.

***Açudes* classification**

The *barreiro* or tanque is a small tank with a rudimentary rustic lateral outlet canal, which dries out every year and is used for cattle drinking as a pond (5,000 to 10,000 m3).
- The small *açude* (10,000 to 50,000 m3) is a land dam barring na intermittent river or streamlet. It can guarantee the water supply during the dry season and make the transition between two rain periods, but it can't face up to a long drought period.
- The medium *açude* (40,000 to 300,000 m3) has a capacity to permit, at least to assure one year of drought (20 months without rain and flow). It is, generally, the main water supply source of the farm.
- The large *açude* is a perennial reservoir when it is not used for irrigation. It is generally a public infrastructure (> 300,000 m3).

Rain fed agriculture

Rain fed agriculture constitutes the principal farming system in the semi-arid region. It has remained rudimentary and submitted to the extreme variability of precipitation. It is, mainly, manual farming, in order to produce food crops (corn, beans, manioc), whose surplus is sold. Agronomic results are weak, because of hydra deficits associated to a very low input utilisation (fertilisers). In fact, contrary to other agrarian civilisations of the Latin American continent, the rural populations of the Brazilian *Sertão* practically did not develop strategies to combat erosion, economise water or to improve local water catchment "*in situ*". That is to say on a parcel scale, using, for example, terraces, contour tilling or agro-forestry technologies. The colonisation and exploration of the Sertão is, however, narrowly linked to cattle breeding, to the availability of large spaces and to the weak marketing integration of the cropping systems[10].

We find, however, three forms of parcel level water management, mainly in the *Agreste* farming systems, less touched by droughts and with a tradition of agriculture. They are furrow making, planting on perpendicular furrows contrary to the downward slope**,** contour tilling, generally associated to the practice of inter-cropping or multi-cropping alleys, here called "*aleias*".

Water management improvement and peasant innovation

Some technical evolutions but limited investments

Traditional systems have progressively incorporated new technologies, endogenous or not. Speaking of domestic supply for example, the *"caldeirões" system* (cauldrons) have lead to diverse improvements in the construction of water-tanks using natural *impluvium* or the tile roofs of the rural houses[11].

Besides the building of large reservoirs and huge irrigation schemes, there were few public investments in the matter of decentralised and local water resource management. However, some alternative systems have been experimented in the last years. They link up peasant diversified knowledge to technological innovations tested or adapted locally. We can give the example of alternative water catchment systems: manual pumps, windmills used to pump water for animal drinking troughs. Concerning underground waters, deep drillings in the crystalline area have shown limited results.

Because of the lack of economical and appropriate sounding methods, they usually reached saline water or very weak flows. Underground dams on the small intermittent rivers present the advantage of reducing evaporation, retaining water in alluvial soils that can be cultivated. However, the diverse models have to be adapted to each particular situation. Because of the lack of complete studies there were very few experiments and diffusion. Reserved for farming use, without storage capacity of drinking water for animals and humans, this system does not respond to peasant priorities[12]. Recent studies had almost proved it could contribute to assure a regular supply for "amazonas" wells, dug down-stream[13].

Integrate and multiple use of land-dams

We will develop here, one of the alternatives of local and productive water management, object of important work of research and diffusion. Its appropriation by farmers and family agriculture has been diversified. The Franco-Brazilian co-operation has formulated proposals for multiple and integrated utilisation of small dams in the frame of the UPPA Project: Productive Use of Small Açudes (box 4). These propositions are concerning the crystalline Northeast semi-arid area. The extreme variability and irregularity of rain distribution and hydra regimes affect the agriculture of the region as well as the reduction of the precipitation[14]. Every year, the main part of the rain is concentrated during a few days, provoking, sometimes, floods. Then the rivers quickly dry. Water-flows, if they are not retained, are not of any use. The main part of superficial reservoirs is ponds used for cattle drinking and, for rural population water supply during the dry season, in spite of grave sanitary problems. Used this way, the majority of the water is practically lost by evaporation and infiltration.The UPPA project (1991-1994) has proposed a valorisation of these flows, generally lost through their catchment and storage in land dams and barring of intermittent streamlets. The technical proposal associates to cattle water supply the implantation of receding irrigation cropping, semi-intensive fishery and the irrigation of small schemes.
One of the main innovations, was the adaptation of a scientific method to determine the specific dimensions of small and medium dams for watersheds with surfaces under 500km2 and of the micro irrigated schemes associated to these reservoirs[15].

This proposal has known diverse adaptation and appropriations according to the diversity of the situations and of the farming systems of the region. We may distinguish three main cases: North Sertão, south Sertão and Agreste areas (figure 1). In the north Sertão (Ceará, Paraíba, Rio Grande do Norte, Pernambuco) there exists a tradition of land-dam making. There is a high density of small *açudes*, generally built without measurements and according to water supply logic (for population and animals). So, besides their high density which strongly limits the construction of new dams on the same watershed, pre-existent açudes are generally localised in places favouring water accumulation (narrow

valleys), or near to the habitations. They rarely are placed up-stream of lowlands easier to irrigate or in basins favourable for receding irrigation practises. At least, their utilisation for drinking water supply forbids fishery intensification, because it implies food distribution and organic fertilisation of the reservoir.

It is the case of the municipality of Tauá-Ceará (figure 1). Small holders with access to medium *açudes* were particularly motivated by the low cost and the efficiency of gravitation irrigation with siphon system on a micro irrigation scheme scale (1 to 3 ha). We must distinguish north and south *Sertão*. The northern area can only count on one rainy season, concentrated between November and April, sometimes restricted from January to march for the driest zone. South *Sertão* and *Agreste* areas can benefit a bi-modal rainfall system: storm rains (*trovoadas*) from November to March and light but continuous rains (called "winter rains") from June to September. In the two cases, complementary water sources or reserves with wells and dams permit the assuring of the cycle of growth of rain fed crops, using ready irrigation systems, also called "irrigation of complement" or "irrigation of salvation". However, the communitary management of irrigated areas and the local marketing of perishable products (legumes and fruits) are the most common problems. Also, the frequent presence of infiltration at the base of the *açude* dike, traditionally used to "*wet*" an orchard or preserve forage crops (*pennisetum*, forage sugarcane), have considerably limited the diffusion of irrigation with small dams. These infiltration locally called "*revências*" can be accidental or planned and implanted at the beginning of the dam construction; certain lowlands down-stream of the *açude* are, almost always flooded, which forbids the use of irrigation.
Priority was given to the irrigation of forage crops that can be better integrated in the strategy of intensification of livestock farming systems. Receding irrigation for floating grass (*Ichnanthus bambusiflorus, Echinochloa polystachia, Brachiaria mutica*, etc.) has, despite the interest of cattle breeders, access, even temporary, to the big public *açudes* edges. In fact, the construction of the main part of small dams in narrow or rocky valleys does not allow for the practice of receding irrigation cropping[16].

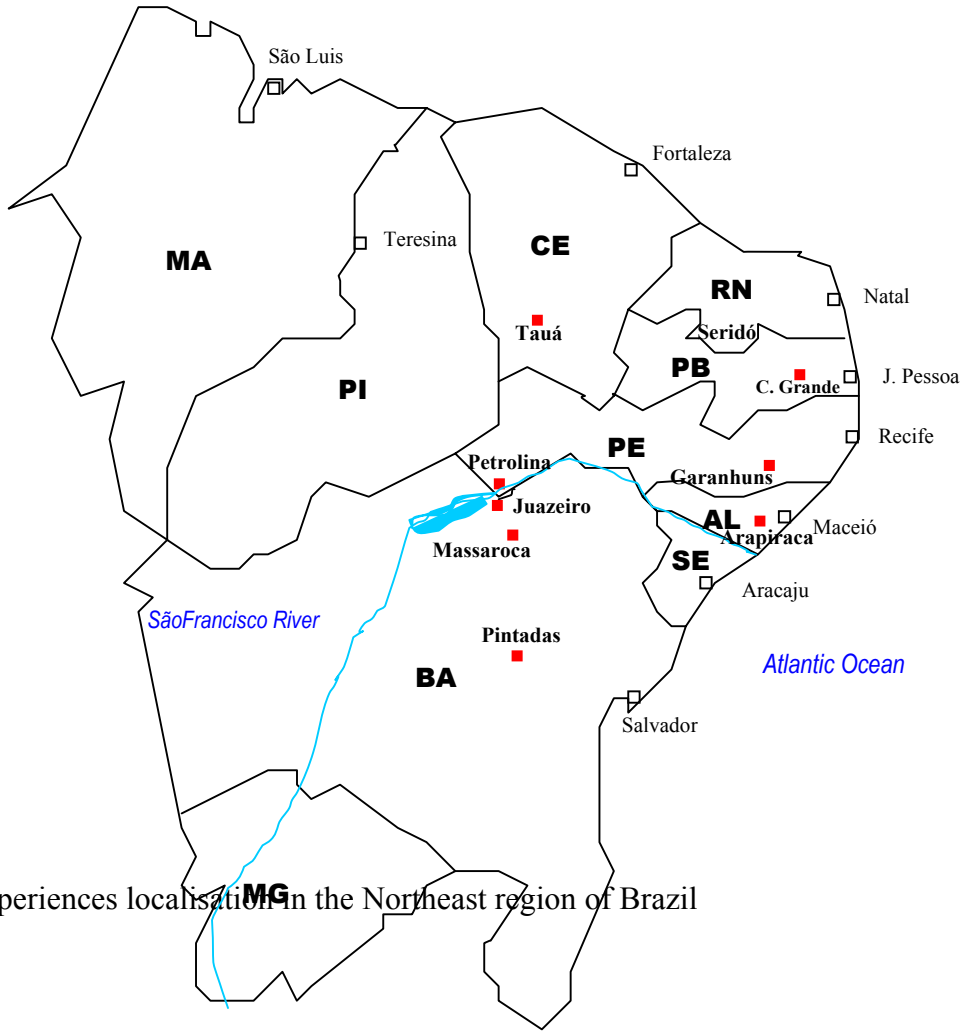

Fig. 1 Experiences localisation in the Northeast region of Brazil

In south *Sertão* (Bahia, Sergipe, Alagoas, Minas Gerais), besides the big public dams for water supply there only exist ponds or very small tanks, called "*aguadas*", "*barreiros*" or "*tanques*" and granite cauldrons. Thus, it represents a "virgin" area for Açude Productive Use Proposal (UPPA). There is, for example, the case of the Municipality of Pintadas, where the small holders' organisation and the opportunity of public financing for a Family Agriculture Support Project have permitted experimenting such propositions on a municipal scale (figure 1). The land tenure was an obstacle to irrigation and *açude* projects because the access to lowlands is extremely parcelled. The small holders organised themselves in proximity groups in order to constitute favourable structures, associating, when possible, dam, irrigated lowland area and receding irrigation area for a common use. It was possible to negotiate access to lowlands in exchange for good pasture lands. For the Federal bank, credit is individual. However, the producers of each group accepted putting them in communal and offered a collective guarantee for individual reimbursements.

These dispositions have permitted technical communitary investments, impossible on a single farm scale: construction of small dams with irrigation system, acquisition of animals, motors and forage mills for silage. Technological innovation became possible because of this real social mutation. Small holders groups were created in 1988 for a ten-year period, corresponding to reimbursement delays. In the majority of cases, they decided to renew the experience. Certain groups have got new credit to build a second dam, constitute a milk production herd or to implant forage crops (*palma* cactus, sweet corn, etc.). Such choices are not easy nor evident. The owners of the lands valorised by the construction of a dam, a silo or an irrigated scheme could have claimed them back after ten years. Thus, for the bank there does not exist a collective agreement. Credit and investment are individual. Social pressure is obviously very strong inside small proximity groups; however, some groups have decided to protect themselves with written agreements, mainly to guarantee the common use of the *açudes* and of irrigated areas. More than 40 small communitary *açudes* with a capacity from 15,000 to 70,000 m3 have been built in Pintadas, in benefit of almost 300 rural families and 100 poor "urban" families.The same proposals were soon extended with diverse kind of success, in more than 20 municipalities of the region by the Bahia State Planning Secretary[17].

In Agreste areas, the UPPA propositions have been tested in the Municipalities of Arapiraca (Alagoas), Campina Grande (Paraíba) and Garanhuns (Pernambuco) (figure 1). There were so many difficulties that this kind of proposal of integrated and multiple use was abandoned. It is very difficult to find small watershed capable of producing sufficient flows because of the transition, sometimes very quick, between sedimentary and crystalline origins soils, generally, permeable. To find an impermeable layer (rocky or clay) to base the dike of the dam is also very hard. The soils are usually rich in salt and water salinisation risk is higher[18].

But, the main limitation of the *Agreste* area is the high demographic pressure, associated to minifundium land tenure. There exists, in reality, very little space and places adapted to build dams, without compromising the access to fertile land, or with the price of complex negotiations between co-owners because of the fragmentation of the parcels. The stored waters are primarily used for animal drinking, when not first for human supply, which forbids irrigation practise and reduces the interest of fisheries.

Limits and challenge for localised water management

Water management practices in the semi-arid Brazilian region and diverse tentatives of improvement, have generally shown a series of limits and common problems. The first constraint is linked to unequal land tenure and distribution that considerably limits access to water, especially when this access, because of new public projects, imposes a change in the relations between big and small cattle

breeders, between cattle breeders and small holders, between landlords and share croppers, small holders and land less. In the case of water management, one of the main stakes of power in the Sertão, technical changes obviously lead to contest the anterior order and the social balance. Successive land division by egalitarian heritage had lead to the fragmentation of small properties, especially in the more fertile areas and in the lowlands. This field pattern makes water resource management harder on watershed scale. It is the same matter for the construction of new dams or drills, the study of their dimensions, the utilisation of water and land (conventional irrigation, receding irrigation, fences, animals drinking troughs or free access for cattle). The implementation of land conservation measures (erosion protection systems, contour tillage, reforestation, fight against water salinisation and pollution, etc.) is also a problem. Projects such as in Pintadas, led by family producers' organisations, shows how the collective establishment of new management rules can help to control this kind of difficulty. The constraint and innovations that are to be considered, are not only of technical or biological order, but also of a social or institutional nature. In the Brazilian Sertão, priority has always been given to cattle and population water supplies. All farming use of water or all intensification as for fishery, enters into concurrence with the water supply logic. This quickly becomes the case for all kind of new hydraulic infrastructure in the defective, isolated or high population density areas. It is also the case when land tenure restrains water access, that is to say, when elementary consumption needs are not satisfied. All kinds of projects or politics for a farming or fishing valorisation of water reserves should first verify the question of the population water supply. In such a case, construction of specific reservoirs can not only avoid concurrence between different utilisation and users conflicts, but also problems of contamination.

The Productive Use of Small Açudes proposal adapted in South Sertão without açudes becoming in spite of the lack of tradition. The construction of new dams has permitted the location and measuring of them according to productive use or specific objectives. Two alternatives are used to guarantee human hydra supply: reserve certain açudes for human consumption or associate them to specific dams for water supply and to the construction of family water-tanks. To satisfy the needs of consumption is not the only constraint for developing productive utilisation of water. Compared to livestock or rain fed agriculture, irrigation imposes on one hand a certain know-how, and one the other hand important investments that the *Sertão* family farmers are not able to guarantee without some support. Other factors are involved: in the Municipality of Tauá, for example, numerous *açudes* associated to irrigated lowlands are not exploited explored any more because of the lack of work forces. The family production unit chief is old, his sons have emigrated .

A decentralised hydra resources management, seeking adapted technical systems diffusion, imposes a link among public actions, collective action and farm scale or individual action. Potable water supply for rural population and protection against contamination and pollution constitute priorities. Without such conditions, no productive incentive policy can be considered. On the matter of public action, the second priority is the decentralised application of land reform measures and the collective negotiation to implement hydra resource management regulation programmes. These measures can be taken on Municipality or State scales. There are some situations where only public intervention can move the social balance which is blocking change. Investments policies should be also established on the bases of negotiation with and among the users, as Pintadas Municipal Water Commission or Tauá Agro-ecological Development Planning. Certain co-ordinations are facilitated by public action, by financial investment or because of the diversity or the number of gatekeepers concerned. For example, in the case of a potable water supply project for the town or the whole population of the Municipality.

Decentralisation of drills, wells and reservoirs has not become a slogan opposing the "small communitary *açude*" or the "big public or private dams". It has to be made available because collective action is working on a local scale and permits the management of water resources, at a low cost and with more efficiency. Collective action, speaking of water resource management, means to seek dialogue and co-ordination among different kinds of users at the same watershed: cattle breeders and

irrigation producers, urban and rural population, artisans and industrials. This is also the case of collective works called "*mutirão*" to clean and maintain "*caldeirões*" and small dams as in Tauá or Pintadas. Collective action is particularly adapted to managing very localised resources interesting small groups: women of the same community, farmers occupying the same lowland[19]. The construction, but above all, the maintenance of water-tanks in Pintadas as in Tauá, have shown the limits of collective goods management. Individual or collective appropriation forms have obviously some incidence on exclusion processes. The Nordeste history is one of the best evidences of this. Collective or public regulation of strategies and attitudes conditioned social and technical evolutions. Water management systems analysis confirm that rural change does not depend only on technological solutions but on economic, social and organisational or juridical innovations. It is based on individual and collective learning processes and on information, experimentation and decision mechanisms. Even if it is mainly made real by producers' individual action on the farm scale, technical innovation techniques involve other organisation levels, those of collective action and public action.

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