Rainwater Catchment and Sustainable Development in the Brazilian Semi-Arid Tropics (BSATs) - An Integrated Approach

The author Johann Gnadlinger works at
IRPAA (Regional Institute for Appropriate Small-Scale Agriculture),
is secretary general of ABCMAC (Brazilian Rainwater Catchment Systems Association)
and vice-president of IRCSA (International Rainwater Catchment Systems Association).

Caixa Postal 21
48900-000 Juazeiro, Bahia State, Brazil
Tel: +55-74-611-6481
Fax: +55-74-611-5385
Email: ircsa@irpaa.org.br

Abstract

During the 1990ies, especially NGOs and grass-root organizations working in the Brazilian Semiarid Tropics (BSATs) have focused on rainwater catchment systems as an essential contribution to people's living under the region's climatic conditions with rainfall only during a few months. Rainwater catchment is seen as one important factor of sustainable development of the BSATs, called "living in harmony with the semi-arid climate." The organizations not only teach appropriate technologies, but first speak about water and climate and then introduce rainwater catchment systems and look at the economic and socio-political conditions of the people involved. There has to be created a political willingness to build an infra-structure such as access to land, animal raising, rain-fed agriculture, water supply, education, health service, streets and commercialization of local products. A joint project was elaborated by the NGO Network ASA called Project for 1 Million Cisterns (P1MC) to be executed by the civilian society in a decentralized manner (at the community, municipal, micro-region, state and regional levels). At a fist stage, 12,400 cisterns where built by ASA and funded by the Ministry of Environment, and further 21,000 cisterns are planned until the end of this year. The goal of the project is to supply drought proof drinking water for 1 million rural households. It is strongly hoped that the new Brazilian government - with its program "Hunger Zero and Thirst Zero" - will promote rainwater harvesting not only for drinking purposes and for animals, but also for agriculture as part of an integrated development program of the BSATs.

Key words: rainwater catchment, semi-arid regions, sustainable development, water and environment, food-security.

"Increasing the productivity of water is central to producing food, to fighting poverty, to reducing competition for water, and to ensuring that there is enough water for nature."
World Water Vision, Commission Report, 2nd WWF

1. Introduction

This paper explores the contribution of rainwater utilization for human and animal water supply and agricultural production in the Brazilian Semi-Arid Tropics, where seasonal, interseasonal and interannual climatic variability among other reasons constitutes a major challenge to sustainable rural development in general.
The emphasis here is on sustainable development, dry climate and rainwater utilization.
In a holistic and systemic approach sustainable development must be considered in its different contexts / environments.
We distinguish three environments, in which rainwater catchment agriculture as part of sustainable development should be integrated (Fig. 1, adapted from Yunlong & Smit):

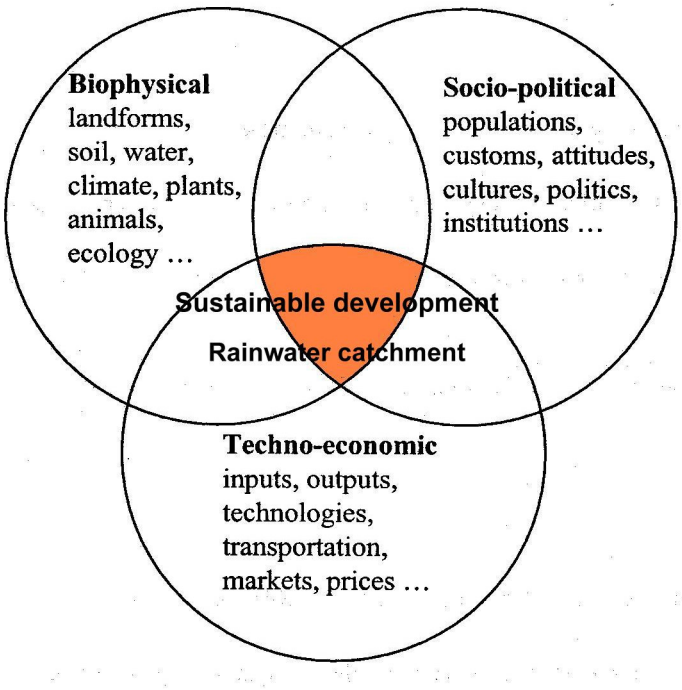

Fig. 1: Environments within which RWU agriculture operates

Rainwater catchment agriculture occurs in (a) the biophysical, (b) the techno-economic and (c) the socio-political environments. These three environments are inextricably intertwined and every factor influences all the others: if one factor within an environment changes, all the other factors change as well. In advance we notice that the complementation among the three environments guarantees to obtain the objectives of rainwater catchment within sustainable development, called **"living in harmony with the conditions of the semi-arid climate."**
To be sustainable, development in general and also rainwater utilization must be biophysically possible, socio-politically acceptable and technically and economically feasible.

2. The biophysical environment is the natural world, which can be viewed as a store of resources available for use by agriculture, some of which are renewable (e.g. plants,

animals, (rain)water and perhaps soil), others which, once used, are effectively gone forever (e.g. fossil fuels and minerals). The biophysical environment is also the stage of nature before agriculture or before major human intervention as shown in Fig. 2 for the BSATS.

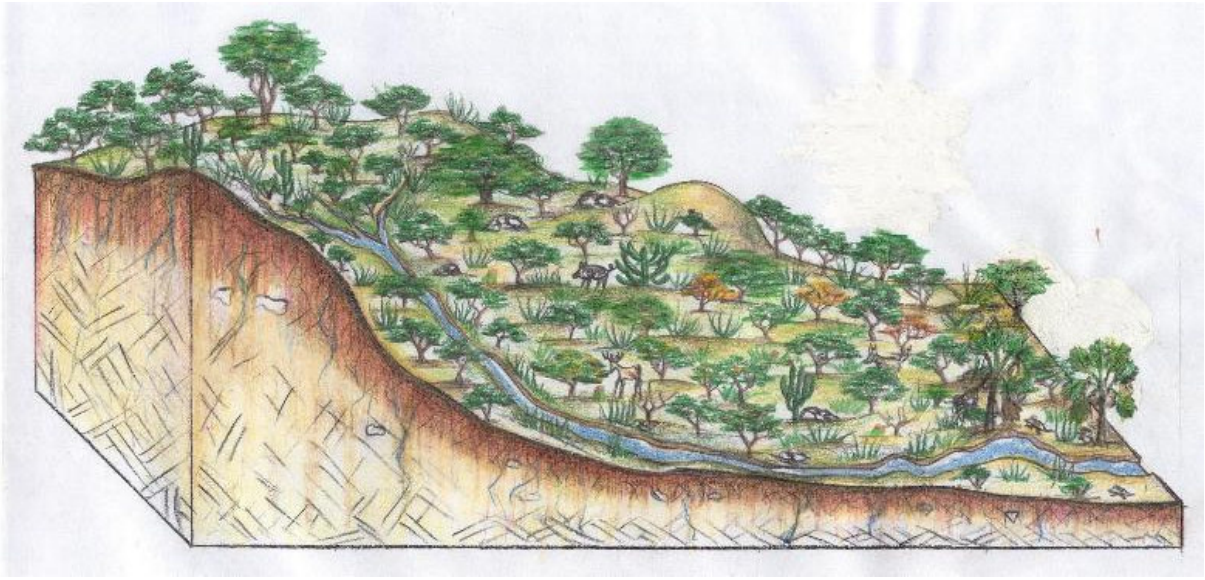

Fig. 2: Scenario 1 - Original semiarid area (Ivomar P. de Sá)

In Scenario 1 (Fig. 2) we see a piece of land (watershed) in the BSATs with no or only little use for agriculture. It is called the Caatinga ecosystem, with an interdependence and interaction between the living organisms and their physical and biological environment. The BSATs or so-called "drought stricken polygon" in the Northeastern part of the country is a region extending over 11% of Brazil's surface, that is more or less 900,000 km^2 (compare Mexico: 1,969,365 km^2, Japan: 377,765 km^2, Germany: 357,011 km^2) and with about 15 million inhabitants.
The BSATs have a regionally and seasonally very uneven distributed **annual rainfall** (between 200 and 1000 mm) in the warm season of the year and a very high evaporation rate (open surface evaporation near or more than 3000 mm/year). But this doesn't mean water scarcity. If we suppose an average annual rainfall of 700 mm, we have about 630 billion m^3 of rainwater in the BSATs. If 88 % of this quantity is absorbed by evapo-transpiration and 4 % infiltrates into the subsoil, there is left 9 % runoff (runoff coefficient 0,09), which is 56,7 billion m^3/year (Vieira) or 3780 m^3/person/year. Supposing that water stress appears with less then 2000 m^3 /p/y and water scarcity with less then 1000 m^3 /p/y disposable water, rainwater could resolve the water demand of the BSATs.
Inside the BSATs, the highest demand for rainwater catchment is in areas with crystalline subsoil, **without suitable aquifers** (very little and mostly saline water only in cracks) and only limited quantity of subsoil water in intermittent river alluvia. This applies to 60 % of the BSATs areas. In spite of the irregularly distributed rainfall, it is possible to catch the rain when it falls, store it and have a reliable water source during the dry season, not only for drinking purposes, but also for agricultural use (Agarwal).
Xerophytic plants are well adapted there to cope with dry conditions: the tree and shrub vegetation Caatinga ("White Wood") is without foliage and white colored during the dry season to minimize transpiration loss. Cacti, Umbu tree (Spatodia tuberosa), Juazeiro

(Zizyphus joazeiro), Waxpalm (Copernicia cerifera) and many others have special water harvesting, storing and conservation mechanisms. Their roots, staying in the surface of the soil, absorb the water from the rain more rapidly. The Umbu tree stores water in the potato-roots (until 2,500 kg/tree) and produces until 300 kg fruits/year/tree.
The soils are mostly fertile sob chemical aspects, but shallow, stony and/or mountainous.
More than 70 % of the Caatinga ecosystem is still intact or with very little human intervention (Conservation International, 2002, but questioned by EMBRAPA: 70 % of the Caatinga has already changed considerably through human activities and in 20 % are nuclei of desertification).
Through agriculture, the semi-arid ecosystem is transformed into an agro-ecosystem.
EMRAPA – Semi-Arido (The Brazilian Agricultural Research Agency for the BSATs) elaborated an **agro-ecological zoning** about land utilization of the BSATs from the biophysical aspect (Guimarães Filho & Lopes):

- 36 % of the BSATs are ecological reservation areas and not appropriate for agriculture,
- 40 % are appropriate for limited agricultural use (goat and sheep raising),
- 16 % permit for rainwater utilization agriculture,
- less than 4 % are appropriate for irrigation agriculture.

In the driest areas of the BSATs as the Sertaneja Depression (368,000 km^2), where sheep and goat raising is the most secure agricultural activity, one needs at least 200 to 300 ha of land to maintain in semi-extensive conditions a herd of 300 sheep/goats for meat production, necessary to enable the reproduction and accumulation of the means of production of one family. One can supply water to the animals by a shallow well or by a rock cistern (caxio). A **land reform combined with the agro-ecological potentialities** of each area is indispensable.
It is also important to consider the latest prevision of the Dialogue on Water and Climate of a **drier climate** for 2020 and especially for 2070 in the BSATs (Appelton). Northeast Brazil will probably become more and more critical in terms of average water availability for livelihoods and the current arid area of Northeast Brazil will experience more frequent low flow conditions of rivers.
The biophysical environment is the stage of nature before major human intervention (Scenario 1). 36 % of the BSATs should continue ecological reservation areas. What do we do with the rest? Two different scenarios are possible, depending on our techno-economic and socio-political interventions.
Scenario 2 (Fig. 3) shows the results of **mismanagement of the BSATs** in full expansion as burning of original vegetation, unsustainable timber and fuelwood extraction, charcoal production, plant collecting, biodiversity loss, modern agricultural expansion, overgrazing, salinization, gully erosion on slope cultivation, soil loss along hill plowing, poor water retention and infiltration, groundwater depletion, drought and flood proneness and desertification.
Connected to these problems faced by the BSATs are the following reasons and consequences as ignorance of dryland conditions, political dependencies, no legal access to land, unpreparedness to living with drought conditions, encroachment to other areas of the BSATs, exclusion from credit and market, migration to cities, etc.
To overcome these problems in the direction of the sustainable development or “living with the conditions of the semi-arid climate”, it is necessary, besides the demands of the biophysical environment, to look at the techno-economic and the socio-political context of the semi-arid region.

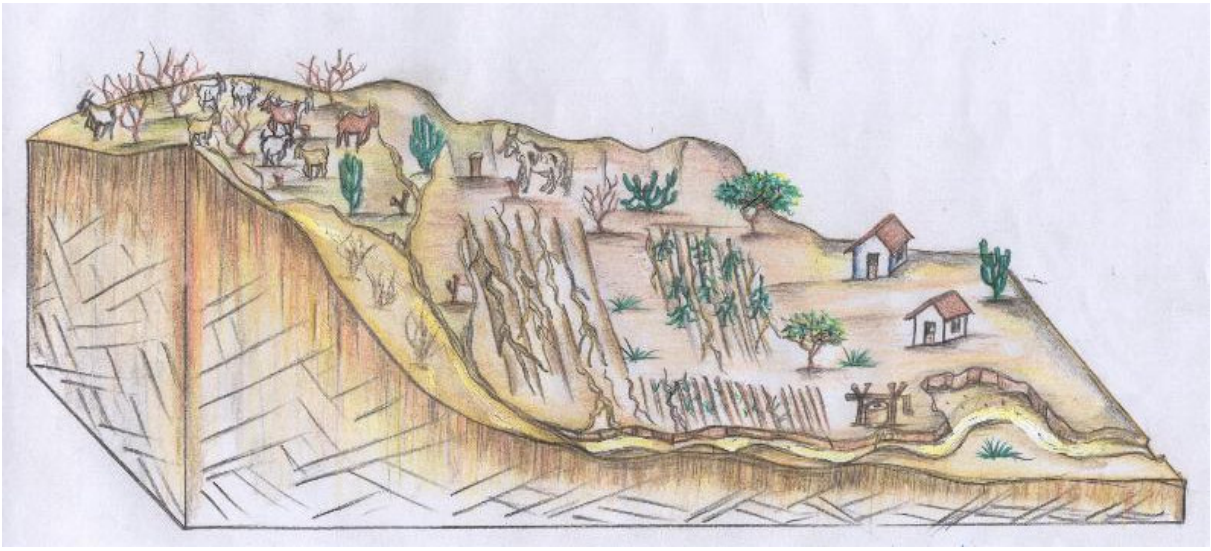

Fig. 3: Scenario 2: Mismanagement of the BSATs (Ivomar P. de Sá)

3. The technological and economic environment increases or constrains the feasibility and viability of agriculture. Changes in input costs and output prices in response to the operation of markets can similarly affect the viability of agricultural activities.
How do rainwater utilization **technologies** enable the water supply for agriculture in the BSATS?
Water utilization methods are classified in several ways, mostly based on catchmnet size or storage type (Oweis et alii), we use here a classification of the type of water use (Gnadlinger 2002[4]). To resolve the water problem in the BSATs, it has to be managed in four ways, using all the available kinds of water supply (ground, soil, surface and rainwater):

a. Providing **drinking water for every household** (supplied by cisterns, shallow wells, etc.): 'No Family without Safe Drinking Water' (Slogan of P1MC - Project One Million Cisterns).

Several tank designs available are already well known and used in the BSATs. The two designs most efficiently regarding low cost are the semi-surface cistern made of pre-cast segments (user preference) and the wire-mesh concrete cistern (sustainability) (Thomas; Gnadlinger, 1999).

b. Providing **community water** for washing, bathing and for animals, supplied by ponds, ground catchment rock-cisterns called "caxios", riverbed-cisterns, shallow wells, etc.; community organization for planning, construction and maintenance is necessary.
c. Assuring **water for agriculture**, supplied by sub-surface impoundments, supplemental irrigation, road catchments for irrigation of fruit trees, contour plowing: minimum tillage with a single tine, use of furrows for storing rainwater *in situ* = inter-row water harvesting, tied ridges; using manure and mulching to store water for plants; planting crops adapted to dry climate conditions (sorghum, pigeon pea, green gram, sesame, etc.).

Sub-surface impoundments, appropriate in crystalline subsoil, store rainwater runoff for a later application: a transversal barrier is dug below the ground surface in a shallow soil (normally 1 to 3 meter deep) of an intermittent streamlet toward the impervious subsoil.

Then earth or rock fill dams are built with a PVC sheet on the downstream face avoiding seepage. When finished, it is possible to plant all types of vegetables, corn, rice, beans or fruit trees, on the runoff watered upstream soil. In addition there is almost always dug a shallow well to use its water for animals or irrigation. Even in the first months after the rainy season, it is possible to plant a second time (Cirilo & Costa). The first sub-surface dams were built in the BSATs more than 50 years ago. During the past years, NGOs as well as governmental agencies carried out experiments and constructed underground dams. Currently there are about 1,000 of these underground dams in operation in the BSATs, mostly in Pernambuco State. Sub-surface dams guaranteed the food security of rural communities even in years of drought as in 1998 or in 2002/2003.

d. Supplying **emergency water** for drought years, guaranteed by deep wells and smaller dams strategically distributed. This point is a transitory solution as long as points **a, b** and **c** are not completely achieved. The common water truck must be replaced, since it supplies not only the most expensive type of water, but also water of bad quality and has been misused to get people dependent on politicians.
e. Including in local water supply planning in the BSATs **water for nature** (protection and pollution prevention of water sources and rivers) as well as **wastewater treatment and water reuse and recycling**.

From the **economic point of view** it is urgent that governmental actions at all levels not only support subsistence agriculture of the BSATs, but make feasible means and mechanisms that help properties of the BSATs to get sustainable at the long term.
The first sustainable plan was elaborated by EMBRAPA in 1985: **Rural Development: How to irrigate 500,000 hectares with small-scale farmers, using rainwater harvesting methods**. In 1993 this plan was reedited by Senator Pedro Simon as an alternative to the project of the diversion of the São Francisco River, but never taken seriously by governments. Recently, the proposals were included in a National Law Project called **Permanent Program of Co-Existence with the Semi-Arid Region**, waiting for approval in the Congress.
According to farmers and technicians, bank credits and loans are normally not accessible to the people, they don't include the necessities of rural people and time of refunding is out of the reality of the BSATs. Among other things, they don't respect the pluriannuality of BSATs agriculture, where pastures grow only in a year of sufficient rain. Earlier this year was launched the commendable **CONVIVER Project – Integrated Action Plan for Living in Harmony with the BSATs –** of the Federal Government, aiming at technological transformation, credits and harvest insurance for small-scale farmers of the BSATS. We mention critically that the plan motivates corn planting – not recommended for the BSATs at former Brazilian Rainwater Catchment Conferences: promising harvest insurance for corn will be expensive for the government and does a bad turn to sustainable development of the BSATs.
For cistern construction there exist revolving funds, motivated by NGOs, local laws, using 3% of municipality budget for cistern construction, and especially the Project of One Million Cisterns (see below).
We hope that in the future cooperatives of credit managed by small-scale farmers will be established.

4. The socio-political environment is concerned with the demands placed on agro-ecosystems and water by people, their cultural attitudes, social customs and basic needs. Growing populations and rising living standards increase both the amount and variety of agricultural products (and water) demanded. Government action and policies exert a profound influence on the way as agro-ecosystems and water are managed.
Different from many other arid and semiarid regions, agriculture (not animal raising) has only been introduced in the last decades in the BSATs. Exceptions are cisterns built by Father Ibiapina in the Paraiba State and the Canudos Movement in the Bahia State in the 19th century. Until some 20 years ago, the local population had neither experiences with rainwater harvesting methods nor the possibility to learn how to live and work in a semiarid climate. Every couple of years vast parts of Northeastern Brazil were affected by droughts which caught the people completely unprepared. As a result, many migrated to the big cities; others were forced to sell their land to big landowners and irrigation farmers for a ridiculous price.
Those strong enough to organize and resist, got together to **develop strategies of dealing with the politics of drought**. "In Brazil' s Northeast there is no lack of water, there is a lack of justice!" was one of the main slogans at that time.
Many people emphasized the importance of water in the BSATs, but defended pumps, pipes, bore wells and the diversion of the San Francisco River and didn't know the **new paradigm of harmoniously living with the climate and natural resources, where rainwater catchment is an integral part.**
This situation begun to change, when EMBRAPA (The Brazilian Agricultural Research Agency) started with **experiments of rainwater cisterns and subsurface dams** in the 1980s. In the 1990s, IRPAA (The Regional Institute for Appropriate Small-Scale Agriculture), other **NGOs, grass-root organizations and communities** began to construct cisterns, emphasized the **necessity of land reform and political organization** as well as **structured educational programs** for co-existence with this kind of climate, in addition to **water management**.
In the following years, EMBRAPA and IRPAA organized various **Brazilian Rainwater Catchment Symposia**, which gave a great impetus to rainwater utilization:

- 1st Symposium 1997: "Rainwater Catchment: the Basis of the Viability of the BSATs": after the symposium different NGOs began to construct cisterns (e. g. 2000 cisterns in the municipality of Campo Alegre, Bahia State) and **EMBRAPA reopened the section for semi-arid agriculture**.
- 2nd Symposium 1999: "Rainwater Catchment: an Answer to the Water Scarcity of the Next Millennium" (this was at the same time the 9th International Rainwater Catchment Systems Conference): the **international participation** of rainwater experts (e. g. from Australia, China, England, Iran, India, Japan, Kenya, Mexico, The Netherlands, Palestine, Sri Lanka, South Africa, Zimbabwe) influenced the Brazilian experience in the following years. A field trip with participants of 11 nations gave ideas about rainwater harvesting and sustainable utilization of the BSATs. During the symposium there was **founded the Brazilian Rainwater Catchment Systems Association (ABCMAC)**. For many people rainwater utilization began to be an important contribution for living in the BSATs and the idea of constructing of one million cisterns has it origin at this conference (see below).
- 3rd Symposium 2001: "Rainwater Catchment and Appropriate Agriculture in the BSATs": There was an **emphasis on rainwater use in agriculture: drought resistant**

plants, exploitation of natural fruit trees, **subsurface impoundments**. ANA – the **Brazilian Water Agency** and other governmental organizations got interested in rainwater utilization; **universities** of the BSATs **got involved** and include rainwater utilization in their curricula.

- 4th Symposium July 9-11, 2003: "Rainwater Catchment and Management: a Sustainable Proposal against Hunger and for Improvement of Live-Quality": It is planned to **join the national campaign of the government "Zero Hunger"**, to extirpate hunger and poverty in Brazil, propagating for the BSATs save drinking water (through cisterns) and food security (through subsurface impoundments and others).

Rainwater harvesting is integrated into regular education

"The present understanding that water has to be managed is misleading. The challenge is rather to manage the people that depend on and make the decisions about freshwater. Contrary to the common-held belief, the water issue is by no means an issue only for experts. It constitutes nothing less than a central question of human survival: water is everybody's business"

12th Stockholm Water Symposium, August 12-15, 2002

Teachers who had participated in **courses on climate, water and appropriate technology** in the Brazilian Semi-Arid Tropics, realized that the books used in schools were about life in the cities in Southern Brazil and didn' t reflect the reality of the rural Northeast. They thought that **schoolbooks should be changed** educating children based on the reality of the BSATs and preparing them **for life in the countryside**. As a result primary school teachers in some municipalities were instructed to teach about life adapted to the semiarid climate. In mathematics, for example, children learned calculating by figuring out if the amount of rainwater falling on a roof will be enough to supply their household with water for the dry season, given a certain water consumption. Together with their teachers children **visited the communities' water reservoirs**, produced **films, pictures and poems** about rainwater catchment and invented fun activities and **didactic games** (e. g. The Raindrop and The Way of Water). Teachers and children organized **public parades**, showing how to resolve the water problem in the rural areas of the county. This way, some municipalities were convinced to spend 3 % of the budget for construction of rainwater cisterns, beginning with schools. This experience has inspired other counties to implement similar programs. The schools following the same principles organized regular meetings and in 2001 founded RESAB – the **Union of Schools of the BSATs**. RESAB carries out the process of mobilization of the different social actors living in the region to renew the political and pedagogical program of the schools of the BSATs.

Women benefit most from rainwater harvesting

Part of the learning process is also specifically directed towards young women reinforcing the idea that they should learn to **build their own cisterns** and in case of marriage make the availability of a rainwater cistern part of the agreement between future husbands and wives. Instead of spending lots of time fetching water, women and girls are able to work in the community or to get further education. Other women plant **vegetables on subsurface impoundments** or **produce and sell jam and juice of fruits** of the Caatinga vegetation, thus creating their own **income**. Thanks to processing and selling umbu fruit women's income is greatly increased. Instead of selling a 50 kg sack of umbu for US$ 1.50, women

earn up to US$ 38.00 by turning an equal amount of umbu into jam and juice. This way, women's empowerment plays a strategic role in **fighting poverty** and **propagating sustainable development** in the BSATs, resolving the water problem and creating their proper income.

Institutional Arrangements: ASA Network (Articulação no Semi-Árido or Networking in Semi-Arid Northeast Brazil)

The **ASA network** is made up of over **700 grass-root organizations** among them NGO's, churches, farmers' unions, asso ciations and cooperatives. It began during the United Nations Conference on Desertification and Drought (UNCDD), held in Recife, Pernambuco State, Brazil, in November 1999. During the parallel forum of the **civilian society**, it was noted that a common activity of almost all groups was cistern construction; approximately 20,000 cisterns had been constructed by community efforts. The success of this activity was shown to the **Ministry of Environment**, as something that could be done on a larger scale. Thus a campaign was launched with the name: 'No Family without Safe Drinking Water'.

A joint 5-year project was elaborated by ASA, called **Project for 1 Million Cisterns (P1MC)** to be executed by the civilian society in a decentralized manner (at the community, municipal, micro-region, state and regional levels). The first stage received funding by ANA – National Water Agency of the Ministry of Environment to build 12,400 cisterns until October 2002. The goal of the project is to supply safe and drought proof drinking water for 1 million rural households (five million people).

A big project with a rather modest but hopeful beginning: Difficulties come from a lack of real political will of the governors to resolve the drinking water problem of the BSATs, but also from the fact that the NGOs have to gain experience to execute such a big project. The situation is expected to change with the governmental program **Zero Hunger**, launched in January 2003. Until the end of this year, there are funds guaranteed for constructing more 21,000 cisterns.

Rainwater harvesting for food security and poverty alleviation

"Structural changes are a prerequisite for the eradication of hunger. It requires the creation of decent jobs, along with better investments, a substantial increase in domestic savings, expansion of domestic and export markets, high-quality health and education provision, and cultural, scientific and technological development."

Brazilian President Lula at the World Economic Forum, Davos, January 2003

As the case of Brazil shows, poverty does not depend on rainfall or climate alone. The poorest regions of Brazil are those with the most (in the North) as well as with the least rainfall (in the Northeast) (IBGE).

Governmental measures such as humanitarian or emergency efforts to support the livelihood of the increasing human population in the BSATs should be replaced by innovative and sustainable alternatives. The big challenge is **income creation** in the rural BSATs, processing goat meat and milk, umbu and other fruits, honey, etc, furthermore the incorporation of the traditionally excluded small-scale farmers into the credit and market system.

With the possibility of **pluriannual planning** rainwater catchment agriculture helps to come out of food emergency programs in drought years; it is necessary to replace annual

drought-prone crops like corn with drought-resistant ones and perennial plants; it is important to plant enough pasture, haying and making silage to have enough food for the animals in the dry season; the construction of subsurface impoundments and tanks for supplemental irrigation should make part of governmental financial programs like CONVIVER. El Niño prediction and drought prevention allow to live with the drought through rainwater harvesting.

5. Activities for the future (From vision to action)

Families living in isolated areas with no access to an organized community might not be able to resist migration to the cities or finding employment as cheap labor in irrigation projects. On the other hand, rural people organized in grass-root communities and peasants associations, who know about the semiarid climate and appropriate production methods, are ready to fight for rainwater catchment systems as well as for all the other aspects facilitating and enriching life in the BSATs. The new Brazilian government will give priority to the Brazilian Semi-Arid Region and began its national wide campaign 'Zero Hunger" in this region of the country, where more than half of the population has to survive with less than one dollar a day. This is not only supposed to be an emergency program, it should lead to structural changes. There are voices, wanting to call this campaign 'Zero Hunger and Zero Thirst" in the BSATs.

Recommendations and impacts

Specific actions of a governmental program to ensure the sustainable and realistic use of the BSATs focused on sustainable development should be considered from the following interrelated framework conditions:

Ecological aspects:

- Stimulate the formation of new and strengthening of existing river basin and watershed committees, where rainwater harvesting is an integrated part of their management.
- Contribute that the semi-arid ecosystems are conserved and/or used in a sustainable way through rainwater catchment agriculture.

Technical and economic aspects:

- Include rainwater catchment as an equivalent component to the surface and groundwater resources to an integrated water resources management.
- Carry out a survey of the water resources in every municipality of the BSATs and elaborate "water plans and programs" to secure a complete water supply of the municipalities, even in drought years.
- Give enough financial support to P1MC – Program for 1 Million Cisterns as the starting point for a wider-ranging program of the development of the BSATs.
- Give priority to sustainable raising of small animals (goats and sheep), especially providing sufficient land, pasture and water for them.
- Motivate the construction of rainwater catchment structures like subsurface dams supplemental irrigation tanks for food supply of the rural population.
- Facilitate credits and loans for rainwater catchment agriculture through PRONAF – National Small-Scale Agriculture Support Program and the CONVIVER Project.

Socio-political aspects:

- Approve the law „Permanent Program of Co-Existence with the Semi-Arid Region" at the national level: This program includes the four ways of water management and is being introduced first by the government of the Piaui State in 2003.

- Give preference to an education for sustainable living in the semi-arid region, applied at primary and secondary schools as well as at universities.
- Include rainwater catchment technology in a project of an appropriate agricultural reform in the BSATs.
- Make rainwater catchment a priority for EMBRAPA Semiarido – The Brazilian Agricultural Research Agency for the BSATs and for the universities in the BSATs.
- Exchange experiences in rainwater catchment agriculture between different semiarid regions of the world (IRCS Conferences, workshops, recognition by the international water community).

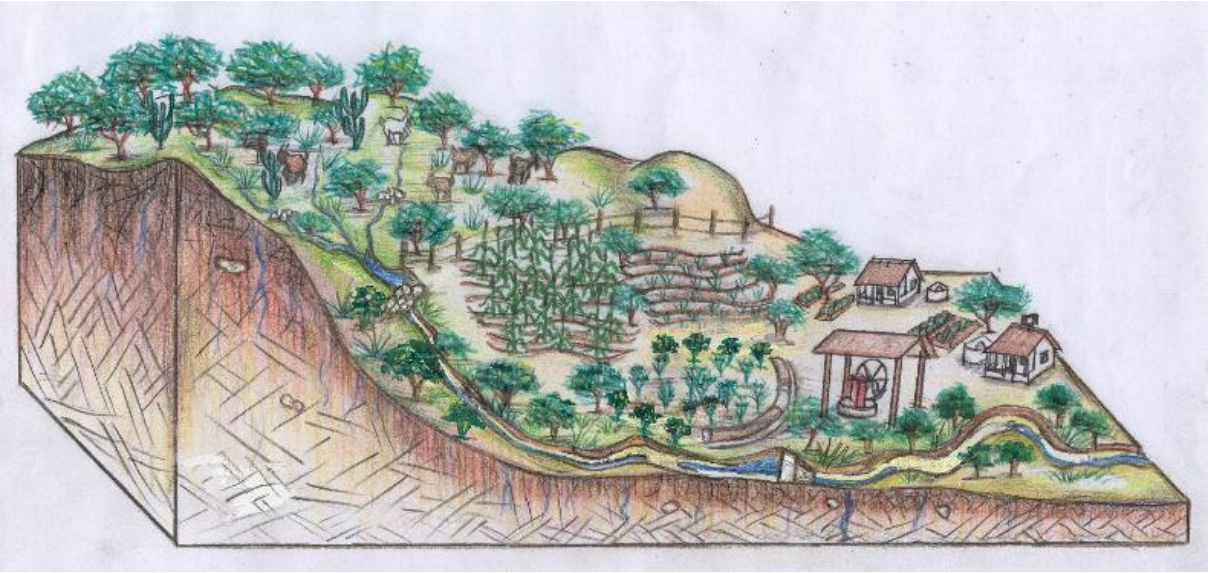

Fig. 4: Scenario 3 – Successful rainwater catchment agriculture in the BSATs (Ivomar P. de Sá)

11. Conclusion

As scenario 3 (Fig. 4) shows rainwater catchment agriculture uses the water fractions that otherwise were returned to the atmosphere through direct evaporation and transpiration by nonfood plants, percolated to the deep groundwater or run off to the rivers.
Development of low cost water and soil conservation technologies, including rainwater harvesting, vegetative soil protection, mulching and terracing can reduce the water risk and lead to substantial increases in yields. As animal raising is more important for a sustainable living of the people than planting in semiarid and arid regions, providing enough water and food for animals is indispensable. A challenge for the future is that increasing the output of rainwater catchment agriculture allows a significant impact in food production of the BSATs. Rainwater catchment agriculture is a starting point of sustainable development in semi-arid regions and is an indispensable part of it, but there are also other important aspects, because it occurs in the broader biophysical, techno-economic and socio-political context, and therefore has to go hand-in hand with agricultural production, health, education, infrastructure implementation, political organization and environmental protection among others.

References:

* 2nd World Water Forum, World Water Vision, Commission Report, The Hague, 2000.
* Agarwal, A., Narain, S. and Khurana, I: Making Water Everybody' s Business. Practice and Policy of Water Harvesting, CSE, New Delhi, 2001.
* Appelton, Brian (ed.), Climate Changes the Water Rules, Liverpool, UK, 2003.
* Caritas of Brazil et alii, Rainwater - The Secret of Coexistence with the Semi-Arid Region of Brazil, São Paulo, 2001 (www.irpaa.org.br).
* Cirilo, José Almir and Costa, Waldir Duarte, Barragem Subterrânea: Experiência em Pernambuco (Subsurface Impoundments, The Experience of the Pernambuco State), 9th International Rainwater Catchment Systems Conference, Brazil, 1999 (in Portuguese).
* Dias, Wellington, Programa Permanente de Convivência com o Semi-Árido, Projeto Lei Nº 1114/99, (Permanent Program of Co-Existence with the Semi-Arid Region), Brasília, 1999 (in Portuguese).
* EMBRAPA-CPATSA, Zoneamento Agroecológico do Nordeste (Agro-ecological Zoning of Northeastern Brazil), Petrolina, Brazil, 1993 (in Portuguese).
* EMBRAPA Semi-Árido, Elementos a serem considerados na Formulação de um Programa de Convivência com a Seca para o Semi-Árido Brasileiro (Elements to be considered for a program of sustainable development of the BSATs), Petrolina, Brazil, 2002 (in Portuguese).
* Gnadlinger, Johann, A Busca da Água no Sertão (Looking after water in the Sertão), IRPAA, Petrolina, Brazil, 2001[4] (in Portuguese).
* Gnadlinger, Johann, Rainwater Harvesting for Household and Agricultural Use in Rural Areas, Presentation at the 2nd World Water Forum, The Hague, Juazeiro, Brazil, 2000.
* Gnadlinger, Johann, Technical Presentation of Various Types of Cisterns Built in the Rural Communities of the Semiarid Region of Brazil, 9th International Rainwater Catchment Systems Conference, Brazil, 1999 (www.ircsa.org.br).
* IBGE, Atlas da Exclusão Social, Censo 2000 (Atlas of Social Exclusion, Census of 2000), São Paulo, 2003 (in Portuguese).
* Krisch, Franziska et alii: Watershed Management, Stuttgart, 1999.
* Miranda, Evaristo Eduardo de (Coord.), Desenvolvimento Rural: Irrigar 500.000 Hectares com Pequenos Produtores? (Rural Development: How to irrigate 500,000 Hectares with Small-Scale Producers?), Ministry of Agriculture, Brasilia, 1986 (in Portuguese).
* Oweis, Th, Prinz, D and Hachum, A, Water Harvesting, Aleppo, Syria, 2001.
* Porto, Everaldo Rocha et alii, Captação e Aproveitamento de Água de Chuva na Produção Agrícola dos Pequenos Produtores do Semi-árido Brasileiro (Rainwater Catchment and Management in Small-Scale Agricultural Production in the BSATs), 9th International Rainwater Catchment Systems Conference, Brazil, 1999 (in Portuguese).
* Schistek, Haroldo, A Construção de Cisternas de Tela e Arame (Construction of Wiremesh Tanks), Paulo Afonso Brazil, 1998 (in Portuguese).
* Silva, José Inácio Lula da: Remarks from President Lula da Silva of Brazil at the World Economic Forum, Davos, Switzerland, 2003. (www.weforum.org).
* Thomas, Terry, Choosing Rainwater Tanks for the Sertão, 3rd Brazilian Rainwater Catchment Symposium, Campina Grande, Brazil, 2001 (www.abcmac.org.br).
* Vieira, Vicente, Água Doce no Semi-Árido (Freshwater in the BSATs), in: Rebouças, Aldo et alii, Águas Doces no Brasil, São Paulo, 1999 (in Portuguese).
* WWSSC, Kyoto...the agenda has changed, 3rd World Water Forum, Kyoto, Japan, 2003.
* Yunlong, Cai & Smit, Barry, Sustainability in Agriculture: a General Review, Agriculture, Ecosystems and Environment 49, pg. 299-307,1994.