HIDROCIDADES - Cities, Quality of Life and Water Resources: Integrated Water Resources Management and Urban Planning for Low-Land Region of Jacarepaguá, Rio de Janeiro, Brazil.

L. Pimentel da Silva[1]*, Fernanda Reinert Macrae[2], Márcia Marques Gomes[1], Luiz Fernando Flores Cerqueira[1], Ezer Urpia Rosa[3] and Marconi Fonseca de Moraes[1]

[1] Sanitation and Environmental Engineering Department, Faculty of Engineering, University of State of Rio de Janeiro, Rio de Janeiro, Rua São Francisco Xavier, 524, Pav. João Lyra Fo., 5o. Andar, sala 5029, bloco F, Maracanã, Rio de Janeiro, RJ, Brazil, 20550-900.
[2] Biology Institute, Federal University of Rio de Janeiro, Av. Brigadeiro Trompowsky, s/nº Prédio do CCS - Centro de Ciências da Saúde - Bloco A - Sala A1-050 Ilha do Fundão, Rio de Janeiro, RJ, Brazil, 21941-590.
[3] Institute for Planning, Rio de Janeiro City Council, Avenida Presidente Vargas, 3131 sala 1204, Rio de Janeiro, RJ, Brazil,20211-110.

**Corresponding author, e-mail luciene.pimenteldasilva@gmail.com*

ABSTRACT
This paper presents practices and measures taken within the HidroCidades Project that have direct effect on minimizing flood risk. These are related to low-cost, novel and integrated ideas that also incorporate income raising opportunities for low-income communities. The work is being carried out mostly in the Cascatinha Community, Jacarepaguá area, in city of Rio de Janeiro, Brazil. Some environmental monitoring and experiments take place outside the Community but with their participation. Previous research revealed that their main problems are floods, rodents and mosquitoes. The methodology of Causal Chain Analysis has been applied for the problem "urban flood" in order to contribute to more integrated effective policies on environmental management. Also, a data base is being developed to support integrated water resources management and urban planning. An experiment involving green-roofs with non-CAM plants that could contribute to income raise is ongoing. Rain water reservoirs are also planned. These actions will contribute to retain rain water and minimize runoff. Authors expect that the results of the project may serve as an example to be taken, spreading among other communities and contributing towards sustainable development for cities in Brazil and other developing countries.

KEYWORDS
Urban drainage; integrated water resources planning; urban planning; low-income communities; developing countries.

INTRODUCTION
Brazil can be considered as an eminent urban country concentrating 80% of its population in urban areas (MINISTRY OF CITIES, 2005). There are 11 main metropolitan areas, among them Rio de Janeiro, with more than 5 million people. The intense urbanization came nearly spontaneously, without effective planning policies. Planning directives were not capable of organizing land use and occupation as to guarantee housing for the majority of the population. As in other cities of the developing countries, the number of informal settlements, especially

in Rio and other Metropolitan areas in Brazil, has been growing. Infrastructure such as drainage and sanitation investments, generally, comes afterwards and is rarely planned ahead. The actual urbanization model has increased impermeable areas which summed with the lack of infrastructure increase chances of urban floods. These informal settlements, generally located on risk and fragile land, such as river banks, low-land, hills, suffer the most. The combined effects of flood, poor sanitation, low economics and education standards in these settlements contribute to the spread of illnesses, social and environmental problems in these communities. Often the problems generated in these informal settlements go beyond of its limits affecting a larger number of people. The problem is complex, having even roots on the colonization strategies for land occupation adopted and calls for integrated measures as more traditional and unilateral solutions have proven economically unsustainable and of none or little effect. The Project HidroCidades is focused on rationalize the use of water by acting in a participatory way with low-income communities that inhabit these informal settlements by promoting environmental education, presenting novel techniques, contributing to influence occupation practices, minimizing flood risk and healthy problems towards promoting social inclusion and improving quality of life to both the formal and informal city. The Jacarepaguá low-land region, west of the center of Rio, is growing rapidly and is the object of study. Action and research are focused on the Morto river catchment which typifies physical environment, land use and occupation and, social-economic characteristics in the region (Figure 1). Some practices and measures taken within the HidroCidades Project that have direct effect on minimizing flood risk are presented. These include low-cost, novel and integrated ideas that also incorporate income raising opportunities for the community. The work is being carried out mostly in the Cascatinha Community, but some monitoring actions and experiments take place outside the Community but with their participation. Cascatinha Community has been objective of a previous research (Cerqueira *et al.*, 2007) in which in interviews the Community pointed floods, rodents and mosquitoes as their main problems. The methodology of Causal Chain Analysis (Marques, 2003) has been applied for the problem "urban flood" in order to contribute to more effective policies on environmental management. Also, a data base was developed to support integrated water resources management and urban planning. In addition, an experiment involving green rooftops is ongoing, as well as rain water reservoirs are proposed as an alternative water supply. These last two actions will contribute to retain rain water and minimize overland flow. Different from most green roofs seen in Europe, this experiment will adopt non-CAM plants, more specifically it will adopt fast growing plants that could contribute to income rising. As the research group interacts with other low-income communities of the Jacarepaguá area authors expect that the results of the project may serve as an example to be taken, spreading among other communities and contributing towards sustainable development for the cities in Brazil and other developing countries.

METHODS

The strategy within Project HidroCidades is to integrate research, action and environmental education to promote faster changing. The project, among others, is focus on flood control. The experiments taken place serve both to scientific purposes and to demonstrate to local people novel techniques that may lead to sustainable life quality improvements. Promote environmental education and governance is also among objectives of HidroCidades.

The research field is in Jacarepaguá, city of Rio, Brazil, which is to where city occupation is expanding. So, the landscape is of transition between rural and urban. In fact, in the past Jacarepaguá main economic activity was agricultural, which has been heritage of colonial farms in Brazil. There, it was selected for the studies, the Morto river catchment at the Water

Park, about 9 km^2 of drainage area. It typifies the physical environment and, social-economic features for Jacarepaguá. In addition, the catchment area nearly matches two census units, which means that all existent Governmental data base that covers many social-economic issues as well as information about sanitation infra-structure such as water supply, sewage and solid waste collection are already available. The former two, are quite closely to floods issues as solid waste and effluents are frequently disposed direct on streams. It is also expected that this will favour future research impact analysis.

A number of meetings were organized in which community people discussed their view about their problems as well as their perception about the possible solutions. These were all documented. At the same time an inventory was carried out in which land ownership were verified, mapping were acquired and eventually completed with some field work, water resources actors, schools, water supply reservoir were all located using a GPS (Global positioning System). This work allowed also, verify visually the streams water quality. Historic streamflow and rainfall data series were acquired from the Water Agency, organized and analysed. These recognition trips to the site supported the location of monitoring plots and choosing the site for experiments such as the green rooftop. In addition, census data set for the catchment were organized and analyzed.

All the information acquired during the inventory phase supported the application of the causal chain analysis methodology (CCA; Marques, 2003; Belausteguigoitia, 2004). Moreover, the Rio´s City Council strategic plan, which is based on opinion research, pointed out strengths and weaknesses for the whole Jacarepaguá region. These were also applied. CCA is a diagnosis tool that traces the cause-effect pathways from the socioeconomic and environment impacts back to its root causes. It involves analysing the physical environment, institutions and social-economic features as well as its inter-relations. Among the objectives of applying the CCA in these studies, are identifying options (policies and actions) to improve water and environmental management in a participatory way towards preserving the environment (natural capital) and improving life quality (human capital). Also, it is expected that the CCA will support future developments on Decision Support Systems.

One of local nearby schools was selected for running experiments, meetings and workshops. The green rooftop experiment should take place on the roof of a two inactive bathroom (separated by a wall) building roof. The strategy is verify and demonstrating the green-roof benefits alleged on literature reviewing such as thermal and rain water retention. It is also aimed on demonstrating that the cultivation on the rooftop could also bring income rising benefits.

There has also been developed printed and internet material. Main authorities related have been visited to raise awareness for region's problems related to water resources, particularly floods. Two workshops should also occur during 2008. These will involve scientists working in HidroCidades, authorities and local people.

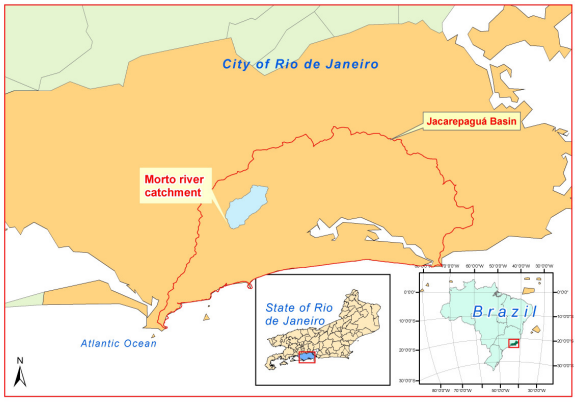

Figure 1. **Morto River Catchment, Jacarepaguá, City of Rio de Janeiro, Brazil.**

RESULTS AND DISCUSSION

Census Dataset Analysis. The last census in Brazil, run by IBGE (Brazilian Institute for Statistics and Geography), took place in 2000. The study catchment comprises two census units (Figure 2). The watershed is nearly coincident with these units' limits. The part that is not coincident is not inhabited. This was important as a large database with social-economic, environmental information is available for these studies. It is also expected that this will favor future analysis about research impacts. Vila Cascatinha Community is located on the right hand side census unit (number 290293) in Figure 2. It was interesting to observe that most indicators are worse for census unit where Vila Cascatinha is located. The illiteracy rate is 4.61% for unit 290292 and is 16.90% (nearly four times) for unit 290293. During meetings at Vila Cascatinha some people revealed that they could not read or write. It was also verified issues such as domestic effluents and solid waste disposal. It was observed at Vila Cascatinha sewage ditches silting (which are also the main drainage streams) and waste into it. This contributes to worse floods as well as their impact, mainly on healthy issues. Pillai (2001) discusses evidences between poverty and environment degradation. The reviewing report shows quantitative evidences that are the poorest that suffers the most at environment risk. It is a cycle that links poverty and environment risks. For sewage disposal only 7.67% of unit 290293 has access to sewage network meanwhile for unit 290292 this raises up to 26.92%. It was interesting to observe that in both units about 17% uses sewage ditches. For solid waste in unit 290292, 97% are reached by waste collection, in unit 290293, however, this percentage goes down to 68.77%.

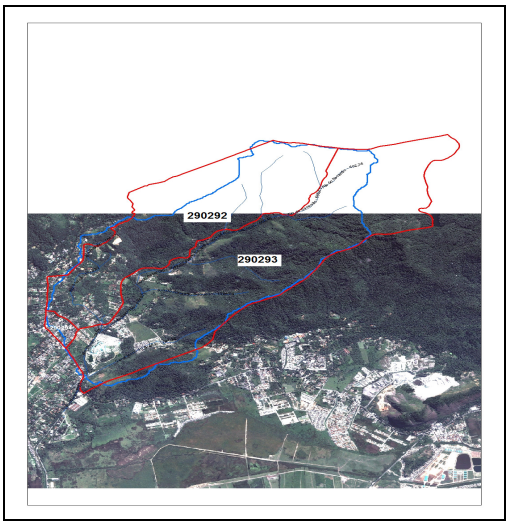

Figura 2. Census Units and Morto River Drainage Area

Water Resources Inventory and monitoring points. Some old streamflow time series data, which run from 1973 to 1980, have been accessed in Rio de Janeiro Water Agency. Figure 3 shows yearly average streamflow and total rainfall. Yearly total rainfall is about 1500 mm. The smallest observed streamflow was 121.4 L/s in 1974 and the biggest 165.6 L/s in 1980. A slightly tendence of increasing streamflow during these seven years can be observed. The analysis of monthly data showed that June and July during winter are the driest months, for which an average of about 70 mm was observed. The wettest months are November, December, January and April with about 180 mm. Some hourly climate data from 1996 to 2006 were available at Jacarepaguá airport which is not too far (less than 10 km) of the study area and temperature data was analysed. Yearly maximum, average and minimum temperatures are shown in Figure 4. Yearly maximum temperatures are around 40°C and minimum around 10°C. These temperature dataset were used to calculate evapotranspiration rates by the Thornthwaite method. Monthly evaporation rates were around 180 mm for

January and around 65 mm for July. Yearly rates were around 1400 mm. Although rainfall and streamflow datasets are not for the same period as temperature dataset, it can be speculate that it should not be verified water deficits at any time in the catchment and that the most critic month in terms of water availability is January. Although rain is at its highest, temperature is quite high as well, raising also evaporation rates to its highest. But it should also be considered that the Thornthwaite method tends to overestimate evaporation rates (Buttler and Miranda, 1984). Moreover, the Thornthwaite method does not take into account either radiation or cloudiness. Although temperature is the highest, as it rains, cloudiness tends to reduce available radiation.

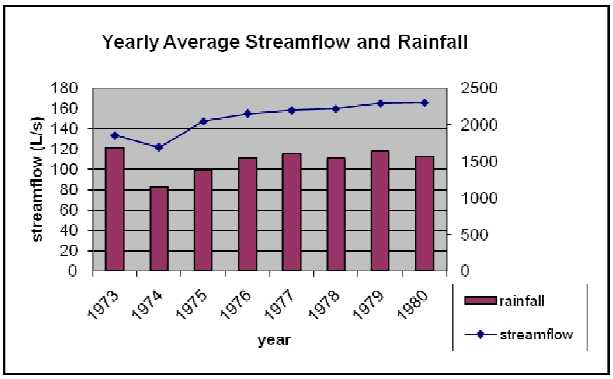

Figure 3. Streamflow and Rainfall for Morto River Catchment

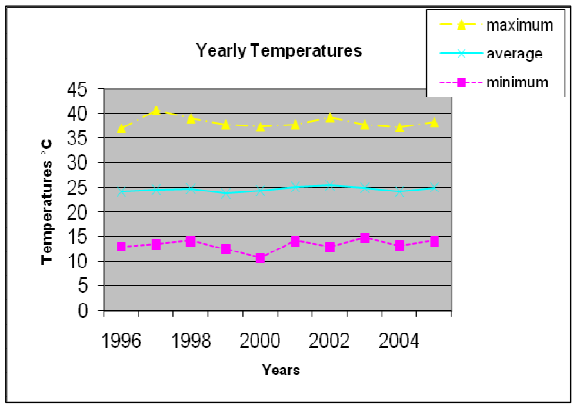

Figure 4. Temperatures at Jacarepaguá Airport

The stream that cuts Vila Cascatinha is named Bruno channel. This is an affluent of Sacarrão river by the left margin. In fact, after their confluence, begins the morto river. Another important affluent of Sacarrão river, is Branco river, which runs on the right margin of Sacarrão. It is upstream at Sacarrão river that is located the water supply reservoir. This is the main source, but many have also shallow wells. The water park, located just before the confluence of Bruno channel and Sacarrão river, have their supply based on deep wells. In visual terms the Bruno channel is the one that presents the worst water quality, although some locals claims bad smelling of Branco river waters. All of them flood on the lower parts. Based on these, monitoring points were located. It has been defined two points for stream gauges where water samples are also collected for water quality analysis. These will be, one at Sacarrão river upstream the water reservoir supply, where a weir has been built, with about 2 km^2 of drainage area, within there is no occupation and; the other is also at the Sacarrão, about the same location of SERLA (Rio de Janeiro State Water Agency) former gauge station

(sampling impacts of occupation), about 9 km^2 of drainage area. Nearby this last one, a pluviometer is going to be placed. They are all automatic with data-loggers. Streamflow should be measured by an ADP (accoustic Doppler Profiler) by SonTeK flow tracker. Apart these two plots for water quality sampling there will be another six collection plots: four at the Bruno channel (one before occupation, one after a Villa located upstream Vila Cascatinha, after Villa Cascatinha, downstream, after the Water Park; another two at Branco river, one upstream before occupation and other at the plot locals claimed water bad smelling. At first, there should be a collection at all plots monthly. For classifying water quality it was considered adequate the US National Sanitation Foundation Index (named IQA in Brazil). This has also been adopted in a number of Water Agencies in Brazil. This involves the following nine parameters: water temperature, pH, dissolved oxygen, biochemical oxygen, faecal coli form, nitrates, total phosphates, total suspended solids and turbidity.

People´s perception of problems solutions. Results showed here are both based on previous quantitative research and on HidroCidades group perception taken from a number of meetings to listen people at Vila Cascatinha about their problems and what they think would be the solution. Previous research (Cerqueira *et al.*, 2007) based on interviews revealed that people at Vila Cascatinha rated floods as the worst problem they have. It has to be considered the effects of flooding in such an environment as Vila Cascatinha, as when streams overflow, this is combined with sewage and solid waste. They also showed to be aware of the resulted impacts such as rats and associated illnesses associated to poor sanitation. When the meetings started after presenting these results people were asked about what they think would be the solution for the floods. They think the solution should be the traditional ones. In fact, they wish strongly to replicate the surrounding formal city within Vila Cascatinha. Have asphalt on pathways, sewage piped dowstreams together with drainage water and then to the sea.
There are many religious congregations within Vila Cascatinha. They seem to have a strong power on people. One of the community leaders takes part in the Catholic Church and the other, to the Universal Church. These first meeting took place in these two churches. But rarely there were people from one congregation on the others church. Talking to people on the streets it noticed that people from other congregation were not invited to these meetings as we asked and never heard of HidroCidades. These findings contributed to propose that workshops, following meeting and experiments should take place at a local school. In addition, it was perceived a sense of pity of own selves. Trusting that the solution for their problems is at someone hands. Waiting to receive land and house, and not trusting on own selves to solve problems.

Green rooftop Experiment Design. Green roofs, green covers, live roofs and other expressions are cited in the literature to explain the use of vegetation over the roofs with adequate drainage and impermeable membrane. Thermal comfort has been demonstrated in a number of studies (e.g. Wong *et al.*, 2003) as a benefit of green roofs. As a result tends to minimize energy costs (Wong *et al.*, 2003). Green rooftops have also a landscape effect. In Rio de Janeiro not many green roof can be seen around. It is seen sometimes in the outskirts and hill cities surrounding Rio. Some public buildings in the city had it adopted on landscape appeal. It is not common to see tops of tall buildings in Rio covered with vegetation. Even in the suburbs, where there more houses, it is not seen often. Green roofs also may retain water minimizing effects of intense rainfall and it is with this appeal it was thought first on this Project.
There has been some Government Projects to improve infrastructure and life quality in low-income settlements, these include drainage projects. However, increase in occupation is a challenge for City Council finance resources and for project designers. Some reports also

demonstrate now that these projects fail in many aspects (Cavallieri, 2000). It has been observed, that as infrastructure improves, people tend to sell their houses and invade other fragile land. This selling is many times illegal, as these projects did not tackle land or houses (generally built irregularly) ownership problems. This is complex, Brazil and city of Rio is not different have land without registered owner or with more than one registered owner. There has been observed an intense vertical growth within low-income settlements in Rio. When houses are built, paving stone is left, expecting finance resources to build on the top. This means an investment, either for selling or rental for income rising. This was investigated in Vila Cascatinha. We have been told that apparently people go to registration offices and register a declaration of letting the place in favor of the buyer. But this has no legal effect. People seem to be aware of that but still do, as removals are rarely verified in practice. There are many complex reasons for that, but political is certainly one of them, as removals do not favor voting and elections. There has been problems of adapting traditional infrastructure solutions to these settlements and adequate these to the budget. These settlements did not have occupation planned, it is nearly spontaneous, and footpaths are very narrow or inexistent. In Vila Cascatinha the access to some houses is the neighbor backyard (many times like an aisle). Sewage ditches are everywhere and access to houses along them is generally a small piece of wood over it that leads direct to the door. As a result, after these projects, floods are still observed. This is mainly the case on low-land occupations.

When the idea of the green rooftops was discussed in the meetings at Vila Cascatinha, the idea was adopting the most common and traditional way of building it, which would imply on house structural reinforcements, so to support plant, compost and water weight. However, it was perceived that people were very interested on that. Everybody wished for house improvements. Nevertheless, the green rooftop aims also to show a different option of vertical growth. It was also realized how important it is that the green rooftop also would show opportunities for income increase.

It was also exercised on a hypothetical well built house the costs for structural reinforcement, impermeable membrane, drainage, compost, seeds and plants. It was verified that these costs might be too high compared to Vila Cascatinha average income.

These findings supported the basis for the green rooftop experiment design in HidroCidades. The main objectives are to evaluate:

- Thermal confort;
- runoff reduction by retaining rain water;
- evapotranspiration rates;
- possibilities on income rising.

In order to achieve the above, the green rooftop experiment is going to take place at a nearby school where lots of children and teenagers that live in Vila Cascatinha go. The school is a democratic and public place, also has multiplying effects. The school chosen has students at age for primary and high school (in the evenings). The experiment is going to take place on the top of a former two bathrooms building separated by a wall. On the roof top there is asbestos tiles. A small reinforcement is going to be done by increasing on the wooden structure that supports the tiles. The plan is divide the roof area available into two parts: one side, about the area of one of the bathrooms is going to be left as it is; the other side is going to receive green cover. This side (green side) is also going to be divided into two parts: one should have rocket planted and the other moss. The impermeable layer is going to be a plastic membrane. The roof inclination is quite reasonable and should be no need for a more elaborated drainage system. Over the plastic membrane the compost layer should be no more than 10 cm. There will be two separate systems to collect roof´s water (for tiles and green

side), so to evaluate rain water retention. Beside the bathrooms buildings there is a water reservoir and this water should be applied when irrigation is necessary. This amount of water is also going to be monitored, so is rainfall. As there is a wall separating the two bathrooms, both internal environments will have individual temperatures registered.

Causal Chain Analysis (CCA). Applying CCA implies first on defining a site and a problem, like a hot spot. In this case it is *floods in Jacarepaguá low-lands*. Follows then, to identify socioeconomic and environmental impacts, its catalysts and their causes, immediate and root. As socioeconomic impacts it has been identified: high rates of poor sanitation illnesses, water supply problems, degradation of water quality and landscape features, potential institutional conflicts such as the City Council responsible for housing and land occupation policies and the State Water Agency responsible for water management towards sustainable development. As environmental impacts it has been identified: degradation of ecosystems, lagoons and rivers water quality, water sources pollution, reduction of fish and reptile species, hydrological cycle changes. Immediate causes for that, were topography (natural cause), Fluvial and lagoons network system (also natural), deforestation, increase on impermeable surfaces, piping of natural streams as well as network rectification, building intensification. The catalysts are demography growth, poverty, low education standards and housing policies which has favoured higher income population. Associated economic sectors were transportation (increase on options as well as increase on access roads), housing, education and professional training, leisure and entertainment (eco-tourism, cinema studios) and agribusiness. Finally, the main root causes were identified as Institutions failures and lack of effective public policies mainly associated to housing and, land use and occupation. Other aspects also related are governance and socio-cultural, such as the urbanization model implying on impermeable areas increasing and the tolerance on disposing sewage and solid waste into streams.

CONCLUSIONS

Project HidroCidades is under development. So, results presented here were focused on the strategy taken and intermediate results such as social-economic and water resources inventory, perception of people about problems and solutions, Causal Chain Analysis (CCA), green-roof experiment design. However, although results are not final yet, some lessons have been learned:

- As in other low-income communities, at Vila Cascatinha the settlement grew in an unplanned way. So, streets and free spaces within the community area are narrow, small and inadequate for traditional drainage solutions such as pipe lines. Moreover, it is, as many others, settled on low land; and topography would also be a problem. This is even more complex considering sea levels are rising.
- During meetings at Vila Cascatinha authors could perceive that people know quite well about their problems and have very strong ideas about possible solutions. These generally are related to traditional solutions that have been proven inadequate in other places, such as pipe streams, drainage and sewage downstream and then to the sea with no previous treatment. When asked about pollution they alleged that many others already do that. There was a general perception about the quite large volume of water in the sea should be enough to dilute effluents. Many people showed a sense of pity of own selves and that should be favoured in some way, have land, house, jobs given by someone, instead of showing own power to change things. There are many Religion congregations within the community. These congregations seem to have a very strong

power on locals. It was difficult to have in the same meeting people belonging to different congregations. This was the main reason to develop experiments and future meetings at the nearby Teófilo School.

- It was interesting to notice that many do not refer to the stream that cut the community land as a natural river but as sewage ditch. When elders said that when they arrived there were fishes in the stream, others seemed disbelieved. These findings are very important to define the strategy for governance and identifying issues for environmental education.
- Many people living in the community are decedents of agriculture workers and are involved in related activities such as gardening in the local Villas as a living. The idea of green roofs was generally well taken, however, it has been perceived a strong will on using the roof to expand housing space as family grows or even for rental, increasing income. Roof tops are also used for leisure (barbecues and small plastic pools). In fact, it has been verified recently "vertical growth" on many low-income settlements in Rio. This enhanced the idea that apart of demonstrating thermal benefits of green rooftops, retention of rain water in the experiment, it is important the strategy to show possibilities of income increase.
- The causal chain analysis showed that the main root causes that contribute to the problem under analysis, *flood*, were Institutions failures and lack of effective public policies mainly associated to housing and, land use and occupation. Other aspects also related are governance and socio-cultural, such as the urbanization model implying on impermeable areas increasing and the tolerance on disposing sewage and solid waste into streams. The catalysts are demography growth, poverty, low education standards and housing policies which has favoured higher income population. Housing deficits for low income population left these people relegated to live on fragile land and under poor sanitation infrastructure. As more data is available it is intended to detail this study in order to enumerate a number of policies and as a result, additions in legislation.

ACKNOWLEDGEMENT

This research has been funded by CNPq under grant 500.129/2006-1. Authors also thank people in Vila Cascatinha Community for their contributions; Teófilo School Directors and Rio de Janeiro City Council; IBGE (Brazilian Institute for Statistics and Geography); SERLA (Rio de Janeiro State Water Agency); INFRAERO (airport climate data). Authors also thank Dr Wellington Mary of Rural Federal University of Rio de Janeiro for advice on cultivation on roof tops.

REFERENCES

BELAUSTEGUIGOITIA, J. C. (2004). Causal Chain Analysis and Root Causes: The GIWA Approach. *Ambio*, 33(12), 7-12.

BUTLER, D.R. and MIRANDA, R.A.C. de. (1984). Comparison between Penman and Thornthwaite Methods to Calculate Potential Evapotranspiration in Southeast Bahia, *Revista Theobroma*, 14(2), 127-133. (in Portuguese Language)

CAVALLIERI, F. (2000). 2000 Moment of Favela–Bairro: Evaluation based on Census 1991 and 2000. *Coleção Estudos da Cidade.* City of Rio de Janeiro Council. Secretary for Urban Planning. Instituto Pereira Passos. Rio de Janeiro: 07 p. (in Portuguese Language)

CERQUEIRA, L.F.F, PIMENTEL DA SILVA, L. and MARQUES, M., Environmental Impacts by Low-Income Settlements in Rio de Janeiro, Proceedings of The 2nd International Congress on Environmental Planning and Management, Technische Universität Berlin, 2007, 311-314.

MARQUES, M. (2002). Proposal of the Causal Chain Analysis Methodology for the Global International Waters Assessment Project. Kalmar: GIWA UNEP/GEP, 30 p.

MINISTRY OF CITIES, National Environmental Sanitation Secretary – Territory Management and Integrated Urban Waters. Cooperation Brazil-Italy in Environmental Sanitation. Brasília, 2005, 270 p (in Portuguese Language).

PILLAI, P. (2001). Poverty, Environment and Sustainable Development: a thematic bibliography. Available at http://siteresources.worldbank.org/INTEEI/2145781112740369617/20486210/PovertyandEnvironmentAThematicBibliography2001.pdf, visited 01 March 2008.

WONG, N. H. et al. (2003). Investigation of thermal benefits of rooftop garden in the tropical environment. *Building and Environment*, 38(2), 261-270.

WONG, N. H. et al. (2003). The effects of rooftop garden on energy consumption of a commercial building in Singapure. *Energy and Buildings*, 35(2), 353-364.