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Full Length Research Paper

Urban tax related to indicators of water quality and quantity upon long-term policy scenarios: A case study of urban conditions at Southeast Brazil

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To adopt new tools of urban development strategies, combined indicators of water quality and quantity were here outlined. This paper aimed to propose a new method of assessment of urban tax (UT$) related to a diversity of water indicators based upon long-term policy scenarios. Thus, in order to promote the monetary values of environmental services, indicators of blue and grey water footprints (WF) of urban drainage, solid waste and domestic sewage were integrated with other indicators at urban lot scale. Besides, a series of equations of UT$ based on organic loads (OL), maximum soil water storage (Smax) and maximum flow (Qmax) were studied and related to WF in the value of urban lot taxes. Four Millennium Ecosystem Scenarios were projected to urban lot systems, through different trends of WF, OL, Smax and Qmax, from current conditions until future planning horizons of UT$ in the period of years 2025 to 2100.Proactive policy scenarios incorporated adapting structural measures in order to minimize the impacts of increasing impervious areas at long-term. Finally, sensibility analysis of UT$ was discussed from a case study of urban conditions at Southeast Brazil.

Keywords: structural measures, non-structural measures, urban tax, urban water management, payment for ecosystem services.

ABBREVIATIONS

BOD: biochemical oxygen demand; N: curve number; GDP: gross national product; IBGE: Instituto Brasileiro de Geografia e Estatística; MA: Millennium Ecosystem Assessment; OL: organic load; PES: payment for environmental services; Qmax: maximum flow; SAAE: Serviço Autônomo de Água e Esgoto de São Carlos; Smax: maximum soil water storage; UT: urban tax on base year (2010); UT$: urban tax; W: weights; WF: water footprint; WfW: Working for Water; WTP: willingness to pay

INTRODUCTION

Urban water resources management presents new challenging questions to long-term about planning growth of impervious areas. To adopt new tools of urban development strategies, combined indicators of water quality and quantity are here outlined.

In terms of Brazil's legislation, the Sanitation's Federal Law nº11.445/07 defines the concept "urban water" as the components of urban drainage, wastewater, water supply and solid waste. However, although there is an incentive to the decentralized management, there is still a methodological emptiness, in terms of indicators that help the Municipal Master Plans.Kawatoko et al. (2011) affirmed that there is still need of in depth studies and solutions proposals in this area. One alternative is the inclusion of taxes in urban lots, in that runoff exceeds the values of base year or the soil permeability reduction reach lower values based on reference year. In Brazil, there are some examples of including environmental incentives on urban taxes, that contemplate the value paid from landuse.

The adoption of structural measures is being more popular in the world, Chang (2010) showed the deep influence on runoff reduction when green roofs on urban lots were instaled.

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Teemusk and Mander (2007) established relationships between efficiencies of green roofs and seasons. The same trend occurs with nonstructural measures, Taylor and Fletcher (2007) established five categories of nonstructural measures on urban water management in their experiments. In Melboure, Taylor et al. (2006) evaluated whether educational campaigns had exercised influence on local habits. In Dhaka, Faisal et al. (1999) developed a series of management water nonstructural measures to contain the floods.

In terms of urban taxes and payment for ecosystem services (PES), Turpie et al. (2008) describes that the government-funded Working for Water (WfW) was created in South Africa, in which certain municipalities entered into payment agreements with WfW to alleviate localized water shortages. Thus, WfW cleared invasive alien plants in the water catchment areas. In China, a survey was conducted with Fuzhou City residents about the willingness to pay (WTP) for control pollution by the livestock farms located at the upstream and values reached 10% of the current base tariff (Jiang *et al*., 2011). In Netherlands, studied cases showed that analytical tools of negotiation analysis provide a useful addition to development of PES, by the establishment of connections between its economic, hydrological and institutional factors (Groot and Hermans, 2009).

Accordingly to WONG (2005), the acceptance of these measures and payments depend on new laws and policies that require balanced strategies for urban water management, as well as, the constant promotion of the benefits achieved.

In this paper, we implemented a new method of non-structural compensating measure as a tool for water management - "Urban Tax" (UT$) - on urban lot scale in order to generate future scenarios that show whether it causes deep influences on water resources management when we adopt water footprint's, quantitative and qualitative indicators, besides structural measures in the neutrality of impacts in urban drainage.

In the work reported here, we projected structural measures (water tank and infiltration trenches), for a 200 m² lot, to be incorporated or not on the non-structural measure, which in turn was determined by hydraulic and hydrologic components of urban water - maximum soil water storage (Smax), maximum flow (Qmax), water footprint (WF) and organic load (OL).

After that, we formed scenarios in time scale, current (2010), 2025, 2050, 2075 and 2100 – Global Orchestration, Order from Strength, Adapting Mosaic and Techno Garden - based on Millennium Ecosystem's methodology (2005), that consists of four prospective scenarios that are divided in proactive and reactive environmental policies. As well as we performed sensibility analyses of non-structural measure in terms of assigned weights of the urban water's components to obtain the monetary value of taxes. These non-structural measures can be established as tools for an adequate water resources management, in this case the "Urban Tax" (UT$).

MATERIALS AND METHODS

"Urban Tax" (UT$)

The proposed "Urban Tax" (UT$) promotes environmental services, in monetary values, adopting the following hypotheses:

if $\Delta Smax$ (t) ≠ 0 , then calculate: $UT\$(t)_S$ = f1(t, $\Delta Smax$); (1)

if $\Delta Qmax$ (t) ≠ 0 , then calculate: $UT\$(t)_{Qmax}$= f2(t, $\Delta Qmax$); (2)

if ΔWF (t) ≠ 0 , then calculate: $UT\$(t)_{WF}$= f3(t, ΔWF); (3)

if ΔOL (t) ≠ 0 , then calculate: $UT\$(t)_{OL}$= f4(t, ΔOL); (4)

In which,

$\Delta Smax$ is the maximum storage;
$\Delta Qmax$ is the maximum flow;
ΔWF is the water footprint;
ΔOL is the organic load.

Therefore, the tax is a pondered balance of environmental impacts (f1, f2, f3, f4) and the weights were established according to municipal laws, in which:

$UW(t)= (W1 \cdot UT\$(t)_{Smax}) + (W2 \cdot UT\$(t)_{Qmax}) + (W3 \cdot UT\$(t)_{WF}) + (W4 \cdot UT\$(t)_{OL})$ (5)

Considering $W1 + W2 + W3 + W4 = 1$; in which $0 \le W1 \le 1$; $0 \le W2 \le 1$; $0 \le W3 \le 1$.;$0 \le W4 \le 1$.

There by, now we will summarize the methodologies adopted to the calculation of the variation of hydrological and hydraulic components.

Maximum Storage

Utilizing CN values and the average CN of each scenario itwas possible to calculate a series of run off parameters. We adopted the "Soil Conservation Service" methodology, established by US Department of Agriculture.

The CN values wereclassifiedaccording to Tucci et al. (1998) for values of soil types "B", in Brazil. Different situations of use and land cover were projected for the urban lot, that exercise influence on CN values, according to each scenario and year. The use and land cover was classified on: impervious area, impervious area directly connected, bare soil, grass and vegetation. So, we calculated the correction equation:

Correction's equation 1:

$$UT\$year = UT_{baseyear}.(1-\frac{S\max_{year}-S\max_{baseyear}}{S\max_{baseyear}}) \quad (6)$$

Maximum flow

The maximum flow was estimated by Rational Method based on the maximum runoff's flows on the urban lot. There fore, the correction equation was:

Correction's equation 2:

$$UT\$year = UT_{baseyear}.(1+\frac{Q\max_{year} - Q\max_{baseyear}}{Q\max_{baseyear}}) \quad (7)$$

Water Footprint

One of the innovations in this methodology is the incorporation of water footprint on environmental incentives. The water footprint was based on Hoekstra et al (2003) and we considered three components of urban water: domestic water, water footprint related to consumption of industrial goods and consumption of meat and agricultural products. In the scenarios, the variations were based on estimative of Gross National Product (GDP).

GDP's estimative and rates of population growth was based on data from "Instituto Brasileiro de Geografia e Estatística" (IBGE), water supply was extracted from providing local service "Serviço Autônomo de Água e Esgoto de São Carlos" (SAAE, 2010), while consumption of meat and agricultural products was calculated through projections of Hoekstra and Chapagain (2004; 2007) and Alcamo et al (2008) that included Millennium Ecosystem Scenarios (MA, 2005).

The projections equations according to Hoekstra and Chapagain (2004; 2007) were:

Water Footprint related to domestic water consumption

$Y=0,74x^{0,53}$[8]
$R^2 = 0,51$
In which:
Y = water footprint
X = GDP's per capita (R$)

Water Footprint related to consumption of industria goods

$Y=0,21x^{0,73}$[9]
$R^2 =0,62$
In which:
Y = water footprint
X = GDP's per capita (R$)

Water footprint consumption of meat and agricultural products

Y = 15,93ln (x) -78,51[10]
$R^2 = 0,74$
In which:
Y = water footprint
X = GDP's per capita (R$)

Therefore, the correction equationwas:

Correction's equation 3

$$UT\$year = UT_{baseyear}.(1+\frac{WF_{uear} - WF_{baseyear}}{WF_{baseyear}}) \quad (11)$$

Organic Load

The estimative of organic load was based on BOD (mg/L) of three components: the wastewater, the runoff and solid wastes. The analyses of BOD followed the Standard Methods (APHA, 1985).
Wastewater values were obtained by SAAE (2010), runoff was calculated by "SCS Method" and solid wastes were based on the "Swiss Method" that accounts volumes of decaying leachate. These values were multiplied by BOD's values (mg/L) of each component and after that, we obtained the organic load. There fore, the correction equation was:

Correction's equation 4

$$UT\$year = UT_{baseyear}.(1+\frac{OL_{uear} - OL_{baseyear}}{OL_{baseyear}}) \quad (12)$$

Millennium Ecosystem Scenarios

Scenarios were based on Millennium Ecosystem's methodology (Figure 1), which considered approaches on environmental policies both reactive and proactive. Each scenario has a trend that guides the values projections of the components approached. For example, in the scenarios, where proactive policies were adopted, we cashed values of maximum storage of structural measures' incorporation. The chosen measures were infiltration trenches and water tank.

For the verification of approaches, we considered on the sensibility analyses, weights of each component studied on "Urban Tax" (UT$), that result in variations of Brazilian monetary values - Real (R$). In graphical analyses, we chose to use equal weights and maximum values were also attributed for each component.

Study Area

The study area is a 200 m² urban lot in São Carlos, São Paulo State, Brazil (Figure 2). The precipitation adopted

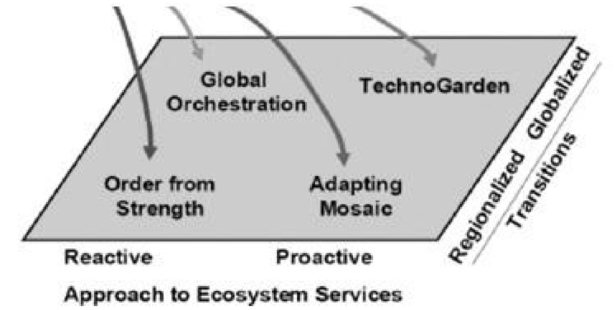


Figure 1: Scenarios from Millenium Ecosystem Assessment. MA (2005)

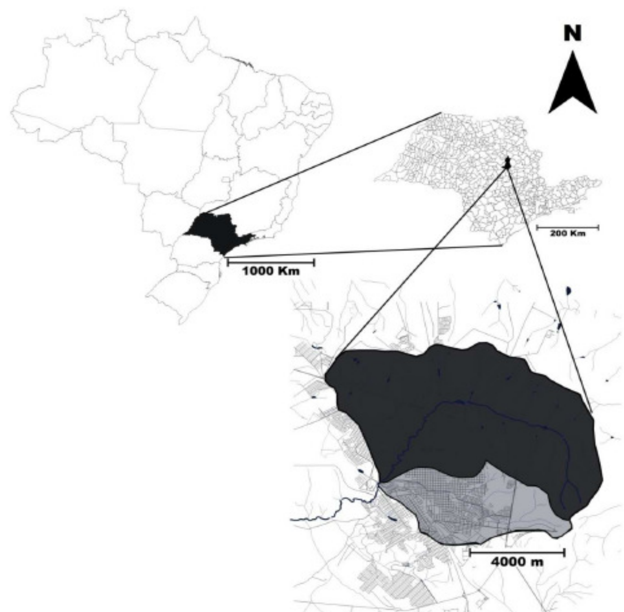


Figure 2: Location of São Carlos. Alvarez (2010)

was the annual average 1505,07mm obtained at the “Weather Station of CRHEA”, belonging to the University of São Paulo - USP (series 1972-2010). The soil’s potential of maximum storage was obtained with CN values established by Tucci et al. (1995) for “B” type soils, the maximum flow was calculated with “Rational Method” of Thomas Mulvaney (1851), the water footprint was based on the methodology established by Hoekstra *et al* (2003), while the organic load was calculated with the organic contribution of wastewater, runoff and solid wastes.

Further more, we adopted the current base value (2010) of urbantax (UT)provided by São Carlos City Hall, which market value was R$ 800,00, under a rate of 0.7% to calculate the *UT$*. The values were used in terms of Brazilian’s currency thus the conversions to other currencies can be established based on exchange rates.

RESULTS AND DISCUSSIONS

For the scenarios that adopted proactive policies, we calculated the following structural measures of urban drainage: infiltration trenches and water tanks. These measures resulted in an increase on the maximum storage about 30,19mm and their effects can be noticed on proactive scenarios.

For each scenario, we calculated the variations of the four components considered on this UT$, by the equations 6, 7, 11 and 12. The variations of Maximum

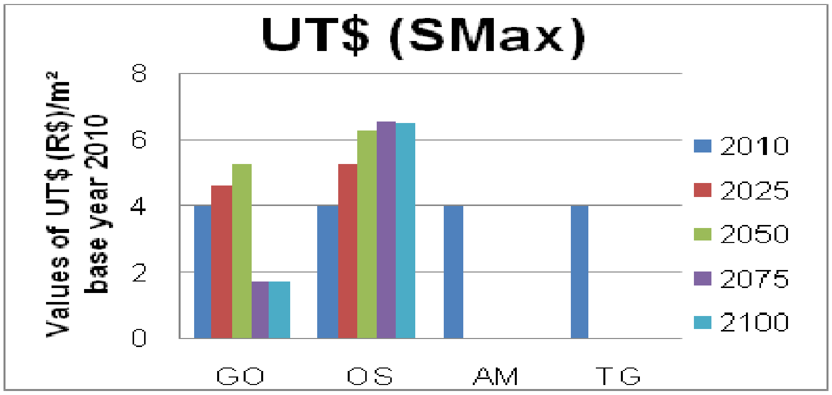


Figure 3: Urban Tax of Maximum Soil Water Storage

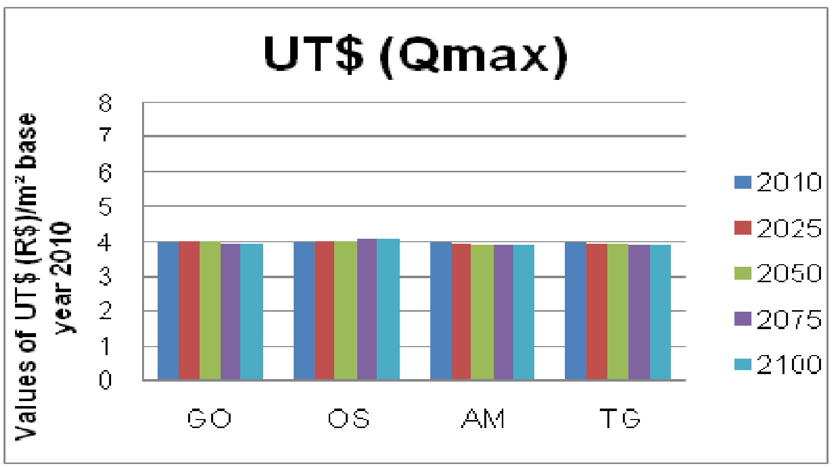


Figure 4: Urban Tax of Maximum Flow

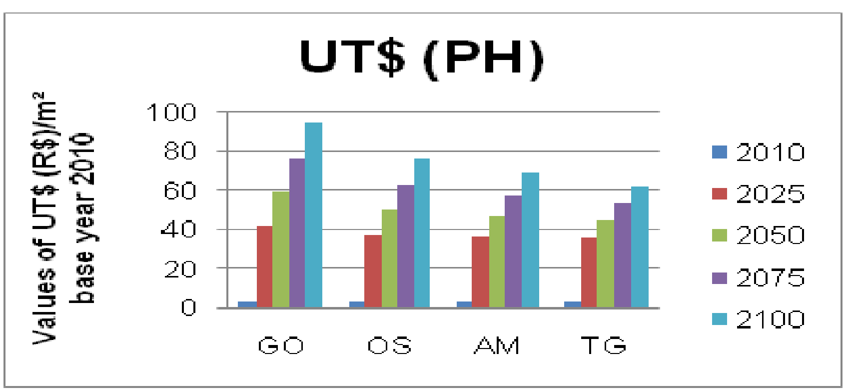


Figure 5: Urban Tax of Water Footprint

Soil Water Storage, Maximum Flow, Water Footprint and Organic Load for the 200 m² urban lot are presented in Figures 3, 4, 5 and 6, respectively. Urbonas and Stahre (1993) affirm that the concept of Best Management Practices was developed from EPA (Environmental Protection Agency) in the 80's in the EUA and it consists

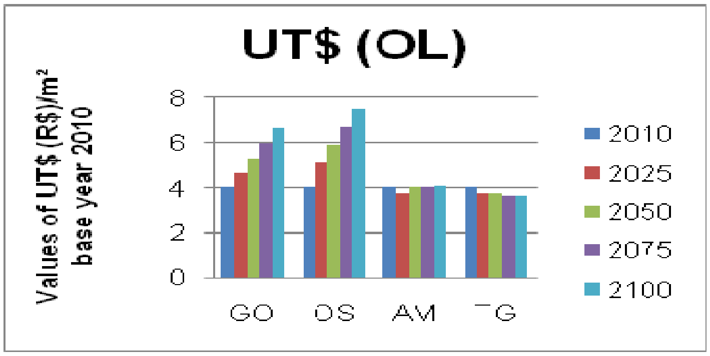
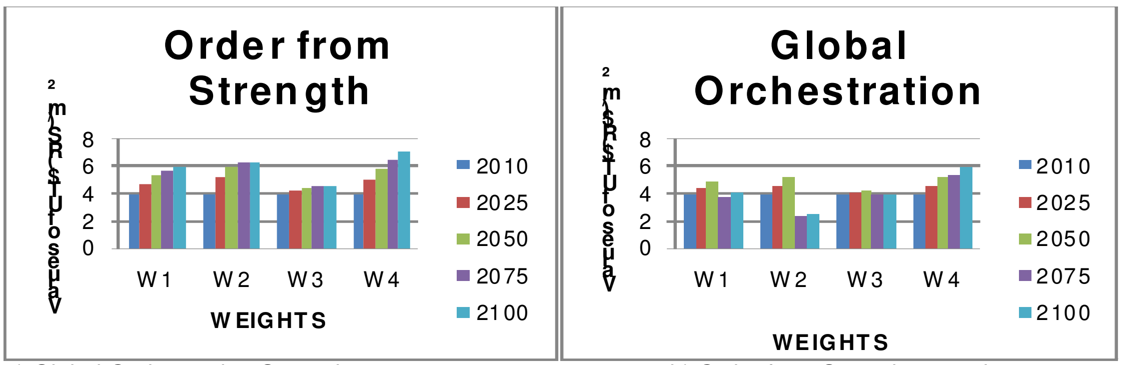


Figure 6: Urban Tax of Organic Load



a) Global Orchestration Scenario b) Order from Strengh scenario

Figure 7: Sensibility analyses of reactive scenarios

of structural measures of contention/detention of water to promote the storage and the runoff infiltration. These measures will exercise a deep influence on "Urban Water tax" values based on Maximum Storage.

The Maximum Soil Water Storage's variation increases on reactive scenarios as Order from Stregth over the time, however this trend reduces in Global Orchestration when structural measures are adopted in 2050, because there is a reduction of runoff. On the other hand, in proactive scenarios, where structural measures are adopted since the beginning, the values of UT$ can reach zero (RS 0,00).

Carvalho and Silva (2006) affirm that the Rational Method developed by Thomas Mulvaney is limited by small areas (until 800.000m²) and it is used when there is a lot of data from precipitation and there is little flow data. Therefore, it is a good method for the calculation of maximum flow.

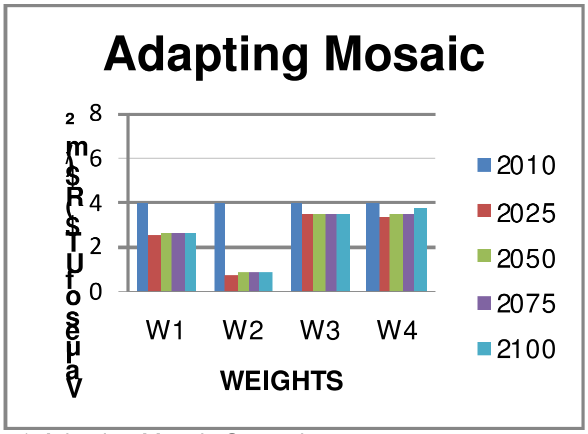
For Maximum Flow's scenarios, the values follow a constant trend because the variations of maximum flow are not significant over the time, even when the adoption of structural measures is considered.

According to projections from Hoekstra and Chapagain (2004), there is a increase trend on water footprint of meat, industrial goods and domestic water over the time. This fact is mainly due to the calculation of industrial goods' water footprint as well as meat, that consume a great amount of water in their processes. Thus, the UT$ based on Water Footprint variations is always increasing, even when proactive environmental policies and structural measures on Adapting Mosaic and Techno Garden scenarios are adopted.

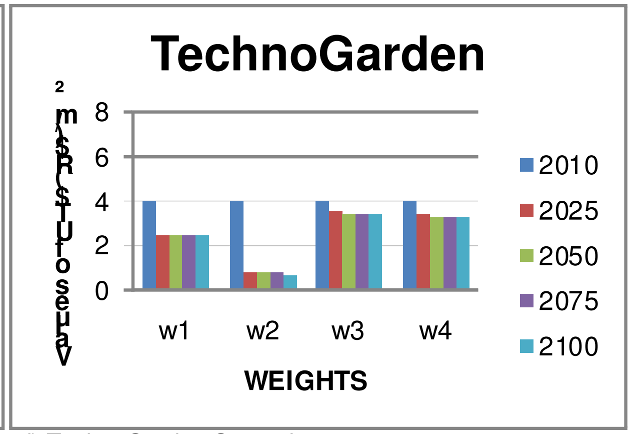
According to Hoekstra et al (2009) the concept of gray water footprint is the amount of water needed to assimilate the organic load, based on standards of water quality. So it is possible to determinate how this organic load varies over the time and calculates a UT$ for it.

In reactive scenarios as Global Orchestration and Order from Strength, the increasing trends are always noticed because there are additions of organic loads from wastewater, runoff and solid wastes over the time on the system. When proactive actions are adopted on Adapting Mosaic and TechnoGarden, values tend to reduce mainly because environmental policies and lifestyle changes are considered.

Thus, the sensibility analyses of weights attributed to variables considered on UT$ calculations are presented in the following figures. The reactive scenarios are shown in Figure 7 and the proactive scenarios can be seen in on Figure 8. In graphs, only weights that considered the



c) Adapting Mosaic Scenario



d) TechnoGarden Scenario

Figure 8: Sensibility analyses of proactive scenarios

maximum value for each component (W2- Smax; W3- Qmax; W4- OL) and equal values (W1) to facilitate the visualizations of the sensibility analyses' effects are presented.

For the Global Orchestration scenario, when equal values as well as maximum values for Maximum Soil Water Storage and Maximum Flow (W2 and W3) are considered, there is an increase trend until 2050 and thereafter a reduction trend, mainly because of structural measures' additions in large scale on a global scenario. However, when maximum values are attributed to Organic Load (W4), there is a increase trend over the time because of incessant rise of pollutants on the system. MA (2005) affirms that this scenario consists to focus on social equity, economic growth and public goods.

While for Order from Strength scenario, there are increase trends in all cases (W1, W2, W3, W4), even those when structural measures were adopted. According to MA (2005), this scenario provides focus on national security and environmental degradation.

In Adapting Mosaic and TechnoGarden scenarios, for all the weights attributed, we noticed a trend to reduce values of UT$ due to structural measures' additions and implementation of more efficient environmental policies. MA (2005) establishes that Adapting Mosaic scenario has focus on integrated management, local adaptation and learning while TechnoGarden consists of green technologies and green economy globally.

Due to the fact that water footprint has a great influence on values of UT$, we developed another sensibility analyses considering this component. Figure 9 shows the sensibility analyses of UT$ also considering water footprint. . In graphs, only weights that considered the maximum value for each component (W2- Smax; W3- Qmax; W4- PH; W5- OL) and equal values (W1) to facilitate the visualizations of the sensibility analyses' effects are presented.

The idea of considering the water use along the supply chains involved, came up with the concept of water footprint introduced by Hoekstra et al. in 2002 (HOEKSTRA, et al., 2003). The water footprint component is deeply influenced by increases of meat and industrial goods consumptions as well as greater acess to goods in development countries (ALCAMO et al., 2008).

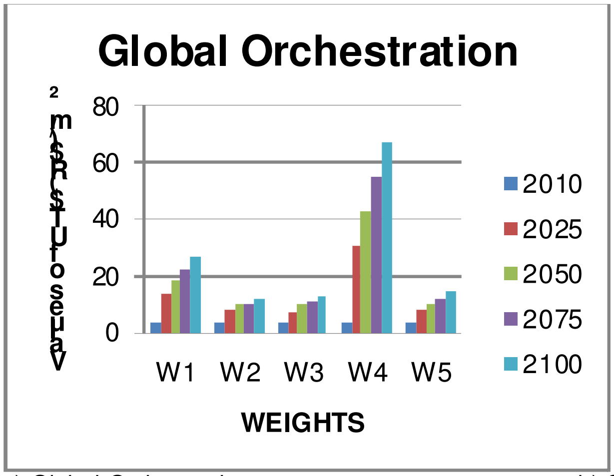
For all scenarios, even when structural measures were adopted and environmental policies were applied, there was an increase trend on UT$, because of the effect of water footprint's addition. This fact shows us that, independent of the scenario considered, water footprint will cause increases on water demand (domestic water, industrial goods, agricultural and meat), what will interfere on taxes values.

CONCLUSIONS

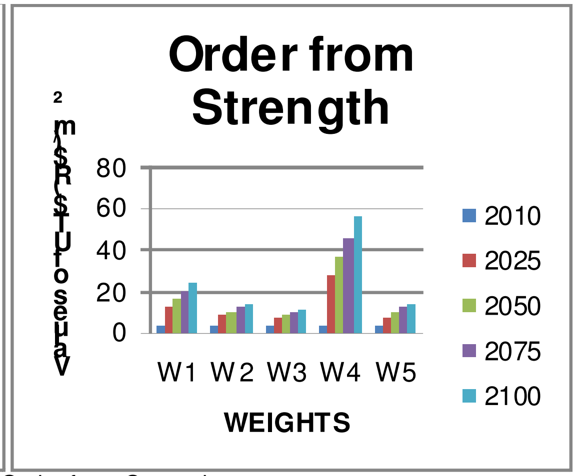
A nonstructural measure was proposed, an urban tax (UT$) based on the environmental service to be paid by the hydraulic, hydrological and qualitative variations over the prospective scenarios. In these approaches, structural measures addition and the water footprint estimation were also considered. After the sensibility analyses, it was possible to establish how much the variation of these components over the time has influence on final results.

It was clear that water footprint exercised deep influence on values of taxes, causing an increase on prices. The Maxium Soil Water Storage was strongly affected by the adoption of structural measures and the Organic Load followed scenarios' variations, while the Maximum Flow didn't exercise great influence on values. Each scenario and component has a trend, however these prospects can change according to local interests.

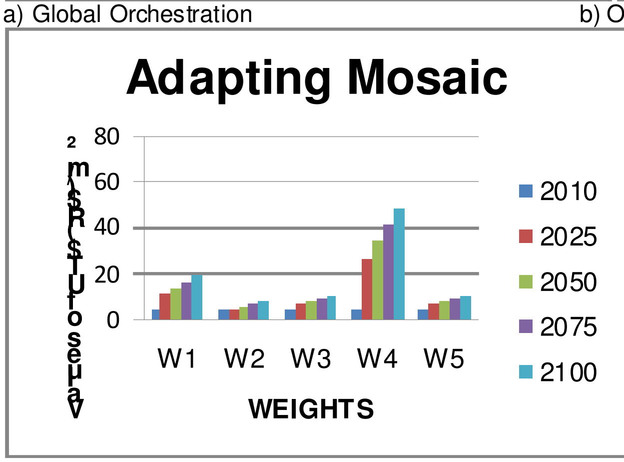
In general, the identification of these influence factors shows us how we can intervene, provide advances in the



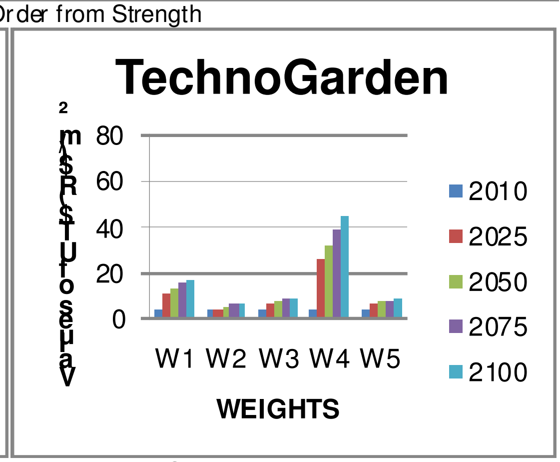
a) Global Orchestration



b) Order from Strength



c) Adapting Mosaic



d) TechnoGarden

Figure 9: Sensibility analyses of UT$' scenarios with water footprint

development of PES and serve as a base to stakeholders to establish new public policies, helping urban planning and being used as water management tool.

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