AN INTEGRATED FLOOD DAMAGE ASSESSMENT IN BRAZIL

A Master's Thesis

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By

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"If you gaze at a single leaf on a single tree, you do not see the other leaves. If you face the tree with no intention and do not fix your eyes on a single leaf, then you will see all the many leaves. If your mind is preoccupied with one leaf, you do not see the others, if you do not set your attention on one; you will see hundreds and thousands of leaves."

Yagyū Munenori

Abstract

The central government of Brazil has taken an increasing lead in risk management in the past few years, the country's dimensions and social and natural variability creates a complex scenario for risk evaluation.

In this study, a framework to assess flood damage risk based on generalized and nationally available data is presented; the approach begins from climate and rainfall analysis and hydraulic hydrologic simulations, followed by an application of normalized flood depth - damage functions and comparison of two different ways to approach maximum flood damage. The first as presented by the European Union Joint Research Committee, an estimation from Gross Domestic Product per capita; the second alternative combines a compilation of previous studies and proposes an estimation of maximum damage based on econometric parameters; making use of taxes and statistics for approaching the local socioeconomic profile of community and production sectors.

The indicators were found in the flood records from 1967 flood event in the region of Porto Alegre, Rio Grande do Sul State from which the relation between those parameters and flood damage was taken. The proposed framework was applied for the city of Irai, Rio Grande do Sul State and compared with damage records. The results from this approach presented a better fit than those calculated directly from the Gross Domestic Product, but additional validation with results obtained in local studies suggests the fitting needs improvement from what is interpreted to be distortions caused by adjusting the initial values across currency changes and high inflation periods in Brazil.

Keywords: Flood, risk assessment, disaster management

The author works for Geological Survey of Brazil

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LIST OF ABBREVIATIONS

ABHSF	Agency of Hydrographic Basin of Sao Francisco, Brazil
ANA	National Water Agency, Brazil
CBDB	Brazilian Dam Committee
CBHSF	Committee of the Sao Francisco River, Brazil
CNAE	National Classification of Economic Activities, Brazil
CPRM	Geologic Survey of Brazil
DNOS	National Department of Sanitation Works, Brazil
FEMA	Federal Emergency Management Agency
GCMs	Global Circulation Models
GIDES	Project for Strengthening National Strategy of Integrated Natural Disaster Risk Management in Brazil
IBGE	Brazilian Institute of Geography and Statistics
ICHARM	International Centre for Water Hazard and Risk Management
ICOLD	International Commission On Large Dams
IFS	Iraí Fluviometric Station, National Water Agency, Brazil
INPE	National Institute of Space Research
IPCC	International Panel for Climate Change
JAXA	Japan Aerospace Exploration Agency
JICA	Japan International Cooperation Agency
NASA	National Aeronautics and Space Administration
PNAD	National Household Sample Survey, Brazil
PNPDEC	National Plan of Protection and Civil Defense, Brazil
RAIS	Annual Report of Social Information, Brazil

RS	State of Rio Grande do Sul, Brazil
UN	United Nations
UNSDR	United Nations International Strategy for Disaster Reduction

1. INTRODUCTION

Flood risk assessment is a task that requires multi-disciplinary approach; concepts from different sciences should be integrated in formats understandable for different sectors of the society. From the community that is affected by floods, to the political leaders, stakeholders and the academia, all should be able to get the wanted answers of this kind of study. This study aims to propose a methodology based on data with nationwide availability, which would be applicable in a municipality scale. The process was to approach several fields of knowledge and choose alternatives in terms of cost-benefit for quick delivery of results, and by optimizing usage of the data that is already available.

The climate pattern and the hydrology the events that control the peak discharges were identified, the extreme value distribution for different sets was prepared to analyze the effects of past climate change, subsequently, the design rainfall was prepared considering temporal and spatial distributions of the events. The discharge and flood were simulated in Rainfall Runoff Inundation model (RRI) software which is provided by the International Centre for Water Hazard and Risk Management (ICHARM), a combination of regional low resolution and local high-resolution hydraulic-hydrological model was calibrated based on previous events in terms of both discharge and of flood extent and all the design rainfall events were simulated.

Following, the available possibilities of damage evaluation were considered and a new approach of estimation based on economic indicators is proposed. The indicators were prepared using assimilation of data from official statistics and from the information available in taxes data. Using the proposed method the flood damage for each return period was then estimated and some discussion of the results and perspectives for the future is presented.

2. RISK MANAGEMENT IN BRAZIL

2.1. Recent Activity of the Geological Survey

The Geological Survey of Brazil – CPRM was founded in 1969 as Company of Mineral Resources Survey (CPRM - *Companhia de Pesquisa de Recursos Minerais*, in Portuguese) as a mixed economy company, which later was gradually transformed to public economy company. It is a Public Company under the Ministry of Mines and Energy. As time passed the company increasingly took more responsibilities and from 1997 the official mission changed to “Generate and spread Geological Knowledge”.

The Geological Survey of Brazil also collaborates with the National Water Agency (ANA - *Agência Nacional de Aguas*, in Portuguese) for operation and monitoring the rain and river gauges network system and operates flood alert systems in 14 basins based in automatic rain and river gauges. the systems operates fully automatically and sends alerts via e-mail to registered users who sign to receive those alerts, also flood maps prepared to be used in conjunct with the alert system are available for seven municipalities.

Sampaio et al (2013) described the legal aspects of how the Geological Survey of Brazil was given more responsibilities after the 2011 disaster in the mountainous region of Rio de Janeiro State; the provisory act nº 547 in 2011, later converted into the federal law nº 12.608 of 2012 (Brazilian Civil House, 2012) changed the responsibilities of the Geological Survey was engaged in several projects in risk management. Ferreira (2016) regarded the PNPDEC - National Plan of Protection and Civil Defense, (Brazilian Civil House of the Presidency of the Republic, 2012) as a good effort in disaster prevention policies, but stated the necessity of better articulation between each sphere of the government, and evaluated that changes will take time.

Three new main projects that were implemented by this action The Emergency Action for Risk Sectoring of Flood and Mass Movements was the first national scale survey on risk areas. The methodology is based on interview with local authorities, media research, field inspections with heuristic analysis and interview with local population that witnessed any extreme events. By 2017, more than 1300 municipalities were visited for fieldwork in risk sectoring. The Susceptibility Chart for Flood and Mass Movements is a product derived from geomorphometric analysis of the terrain, the slope patterns susceptible for landmass movements are estimated based on scars from recent landslides and extrapolated for the municipality and the flood areas are identified by geomorphology as the flat floodplains and alluvial terraces. The Geotechnical Chart for Urban Suitability Towards Natural Disasters is based on the soil type and heuristic evaluation in the fieldwork, which utilized previously prepared Susceptibility Chart and was accompanied by local Civil Defense or experienced professionals, when available. Notably all products of the company are of free access and available from the CPRM Website.

From 2013 the GIDES ($CPRM_1$ – website) project in a partnership with JICA was established to improve the methodological approach for identification of hazard and risk areas for landmass movements. The project lasted for four years and the implementation of the new methodology is on course. For flood risk mapping, new alternatives are being considered to improve and expand the analysis currently performed.

For this reason, this study gave priority to usage of data that was available in national scale, rather than selecting an area with specific studies or researches. The method presented here is applicable, within its limitations, to any area on the country, and the process is described as detailed as possible to allow replication or extension to other areas.

The Sendai Framework for Risk Reduction (UNSDR, 2015) set Global targets with objective indicators for disaster risk reduction, those targets were later detailed by the expert group , the pursue of achieving the global targets A, B, C, D and G can be directly pursued by development of studies in the framework developed in this study even if for each step several other approaches can be made and many studies discuss the individual potentials and limitations of them.

"*Priority 1: Understanding disaster risk.*

Priority 2: Strengthening disaster risk governance to manage disaster risk.

Priority 3: Investing in disaster risk reduction for resilience.

***Priority 4: Enhancing disaster preparedness for effective response and to "Build Back Bette*r""**

Priorities established in the Sendai Framework (UNISDR, 2015).

2.2. Water Rights

The river rights in Brazil were first considered in the Monarchy Stage, when royal monopoly of caudal rivers was declared even before the Imperial Constitution of 1824, the agricultural rights were established in 1804 (Pompeu, 2001), in the Republic-stage the first Water Code was approved in 1934 (Brazilian Civil House of the Presidency of the Republic, 1934) and was heavily modified since then. The Constitution of the Republic, Title III, Chapter II, Article 20 – III (Brazilian Civil House of the Presidency of the Republic,1988),establishes the rights of the Union on the rivers and lakes that serve more than one State; the Title III, Chapter 7, Section IV, Article 43, second paragraph – IV already establishes priority of the Union over the usage of rivers and dams giving priority to social and economic usage of water.

According to Vitória (2013), until 1997 the main objective of the legislation was to assure the rights on hydroelectric power generation. After the privatization of electric plants a new Water Law of 1997 (Brazilian Civil House of the Presidency of the Republic, 1997) was established Spinola (2016) described this law as inspired in the French code, this law incorporated several aspects of integrated water management such as environmental and social causes and intended to decentralize the management. Engle & Lemos (2010) also made a review of the Water Law of 1997 and discussed the adaptative capacity towards the climate change based on governance indicators.

Formiga-Johnson & Kemper (2005) studied the creation of the national code and the State codes that preceded what the author considered a new era, as the 1997 code embraced the principles of Dublin (ICWE, 1992) prioritizing water supply rights to human and livestock rather than power generation. Porto & Kelman (2000) described the new tools of the institutions to achieve such goals, like selective water pricing, issuance of water use permits and other regulations.

Still, some conflicts between levels of government happen in rivers that crosses more than one State of the Federation, such as the case of the transposition of the Sao Francisco River, which crosses the semi-arid Northeastern region of the country. According to Villa (2008) the idea of the transposition was first registered in 1818; by 2003 the central government manifested the intention of building the massive structure of roughly 600km of aqueducts. The States of *Ceará, Paraíba and Rio Grande do Norte* are not naturally supplied with water from the river.

Spínola (2016) described the process in which the Committee of the Sao Francisco River (CBHSF – *Comite da Bacia Hidrografica do Sao Francisco*, in Portuguese) allocated a maximum discharge of 36m³/s and criticized the central government decision of implementing a structure for 91m³/s, as the CBHSF should have sovereignty to deliberate on the usage of Sao Francisco River water. Cerqueira(2017) made an analysis of the factors that impeded the taxation of the water, which initially was one of the resources the Agency of Hydrographic Basin of Sao Francisco (ABHSF – *Agencia da Bacia Hidrografica do Sao Francisco*, in Portuguese) could use to control the water usage.

In flood risk management the large scale interventions such as levees, flood retarding basins and flood control dams have a large impact in the pattern of water availability. This type of intervention brings changes to the whole basin; levees or other river works built upstream might intensify the flood in downstream, while flood control dams and retarding basins upstream might affect greater distances in terms of flood reduction. Mello (2014) emphasized the institutional difficulties on implementing basin wide interventions after the extinction of the National Department of Public Works and Sanitation in the early 90's.

Due to this large scale effect, and due to the high cost of this type of structure, the discussion and decision over them should be done in the river basin Committees; the *Uruguai* River Basin as an example has frequent floods affecting *Santa Catarina* and *Rio Grande do Sul* State in Brazil and also in the border region cities with Argentina and downstream of *Uruguai* and Argentina borders. If a complete damage assessment was made within the basin, a feasibility study could be performed for large scale flood control structures; the cost and benefits of such interventions could be shared among all the counterparts and improve multilateral relations with neighboring countries.

2.3 Objectives

The objectives of this study are to propose a methodology for flood-damage risk assessment usable in municipality scale for Brazil, based on nationally available data. Secondary objectives are to assess past climate change effects and to test and discuss the validation of the proposed methodology and alternatives.

2.4. Location of study area

The study area chosen for application of the methodology is the municipality of Irai, located in the Rio Grande do Sul State in Brazil (Figures 2.1, 2.2, 2.3), the municipality is located in the border of the Santa Catarina State. The border is defined by the course of the Uruguai River, which is therefore under Union jurisdiction.

Figure 2.1 – Location of Uruguai River Basin (Modified from IBGE, 2000)

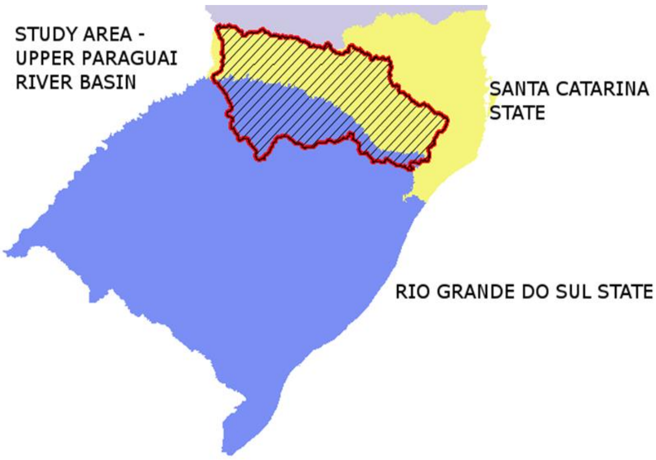


Figure 2.2 – Upper Uruguai River Basin and Political divisions in Brazil. (Modified from IBGE, 2000)

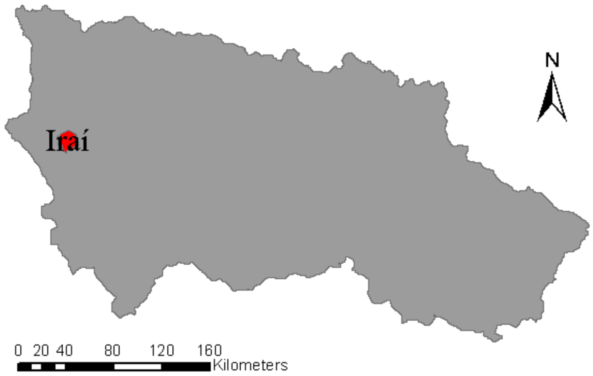


Figure 2.3 – Location of the municipality of Irai in the Upper Uruguai River Basin

Righi & Robaina (2010) made a data survey on flood events in the Uruguay River Basin within the Rio Grande do Sul State (RS), reporting 7 large flood events in the city of Irai in the period from 1980 to 2005.In the past decade, several flood events with losses were reported in the media as example of the years 2011, 2014, 2015 and 2017. Irai flood risk areas were mapped in 2015 by the Geological Survey (CPRM, 2015) which found 1360 from the 7961 inhabitants, or roughly 17% living in high or very high-risk areas. The report also mentions an effort of the Geological Survey to install a flood alert system in Uruguai River.

2.5 Methodology

The methodology proposed in this study is based only in data available country-wide for Brazil, beginning from an analysis of the past climate change within the records, the patterns of rainfall that control the peak discharges and causes flood was identified, following by an extreme event probability analysis. Subsequently the rainfall of selected return periods was prepared considering temporal and spatial distribution. The data was input for a hydraulic-hydrologic model, which was calibrated using river discharge records and satellite imagery. From the simulated flood areas, a normalized damage curve (Huizinga 2017) was used to estimate the percentage of maximum damage caused in each area. The urban areas were identified based on the population grid and the intersection determined the percentage of damage caused. The percentage of damage was then applied in maximum damage calculated based on a few approaches and a function based on the econometric profile prepared from tax and statistics data is proposed to estimate maximum damage for economy sectors.

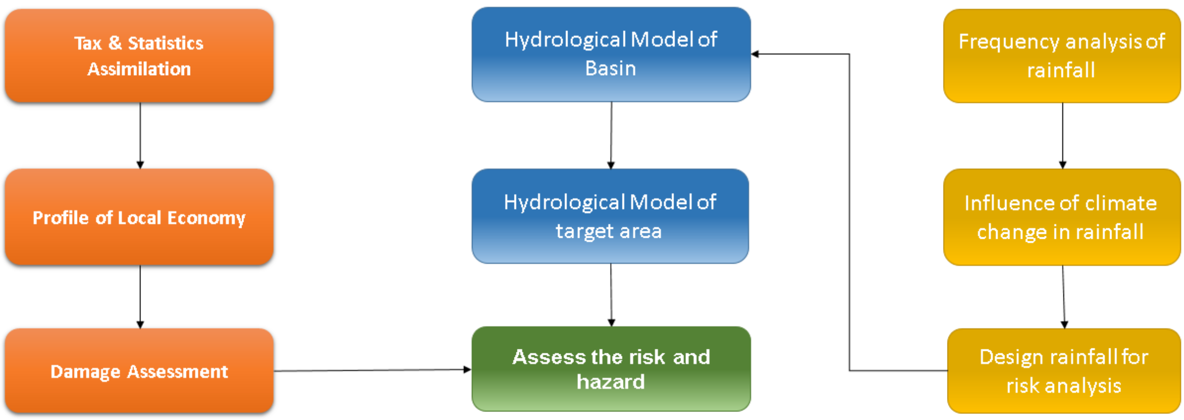


Figure 2.4 – Fluxogram of methodology workflow

3. CLIMATE AND HYDROLOGY

3.1. Rainfall and Climate

The rain gauge and rainfall data was downloaded from the ANA (2017), in the period from December 2017 to June 2018 both directly from the Hidroweb platform and through the QGIS plugin ECODownloader (Petry et al. 2017). The considered data used in this study is presented in the Appendix A.1– Relation of Rain Gauges and Fluviometric Stations and A.2. – River Cross Sections.

The data was organized using the processing tool *Manejo de Dados do Hidroweb* (Fan, 2010) and further compiled in a spreadsheet in MS Excel. Figure 3.1 illustrates the number of gauges that were simultaneously active since 1912 until 2017, notably from the 1950's some average number of stations was maintained. For this reason, the period of 1950 – 2017 was used to study the past climate changes that occurred in the basin in order to assess the dimension of the change that has already occurred within data that was produced by no other than the ANA itself. The most precise method for analysis should involve an spatial distribution of the rainfall for each time one gauge is activated or deactivated, considering that a total of 165 gauge stations were analyzed and an average of 80 gauges was simultaneously active in the period, this would result in several spatial distribution maps and that analysis would consume an extraordinary amount of time, for this reason only, this was not considered a priority for this research, which assumed constant acceptable spatial distribution, but future research including the described procedure is not discarded in improving those results.

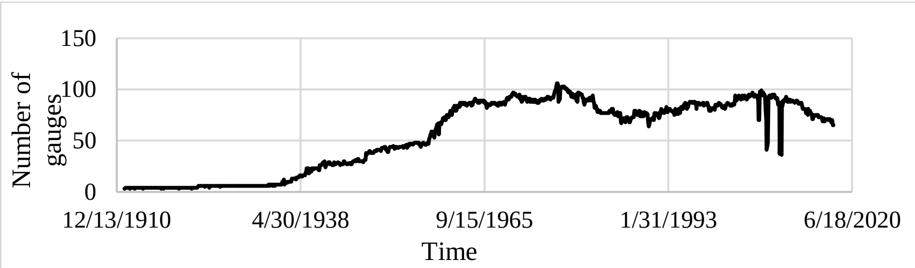


Figure 3.1 – Number of available rain gauges over time (ANA, 2017)

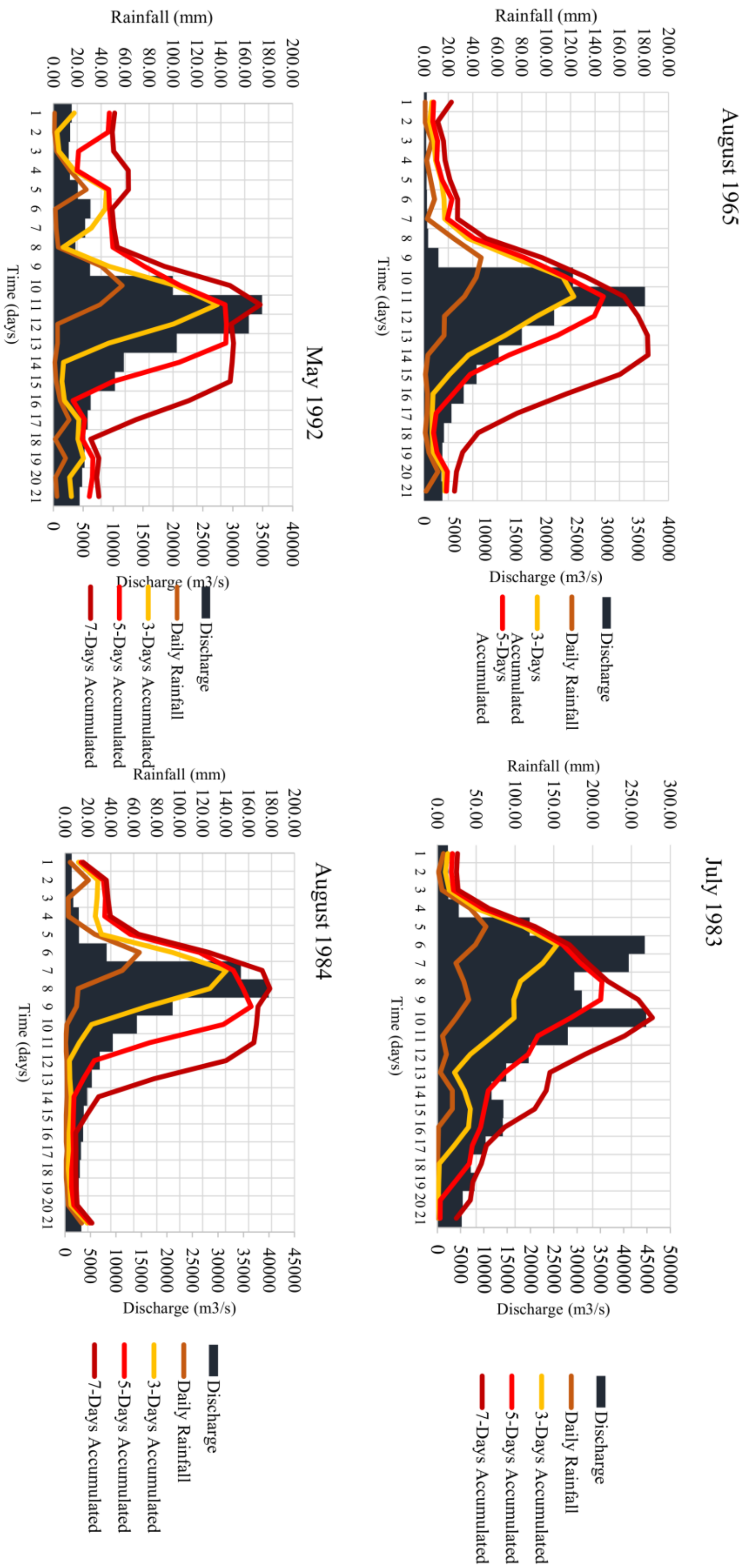


Figure 3.2– Accumulated Rainfall and Discharge

For the consideration of frequency of rainfall, and to assess the past climate change, the probability was calculated in a Gumbel (1941) distribution, as instructed in Maidment (1993) for three different sets of data, firstly for 1950-1987, then for 1950-2014 and lastly for 1987-2014. From this data sets, the frequency for daily rainfall and for accumulated daily rainfall in three and five days were calculated as shown in the figures 3.3, 3.4 and 3.5.

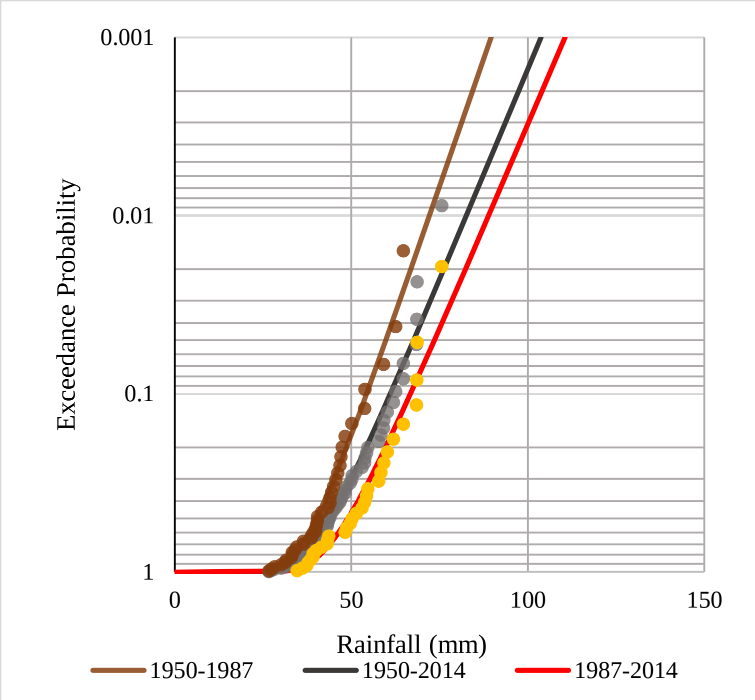


Figure 3.3- Exponential Paper of Gumbel Distribution for daily maximum rainfall

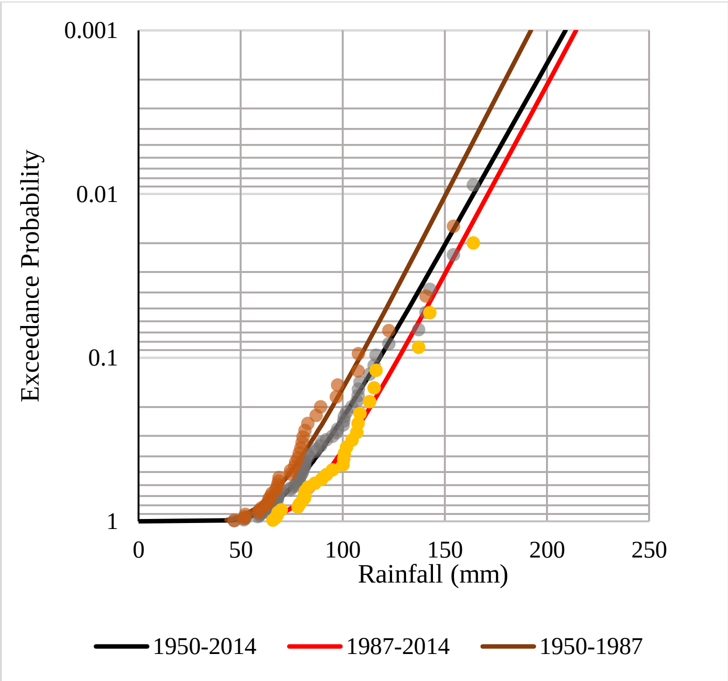


Figure 3.4 - Exponential Paper of Gumbel Distribution for 3-day accumulatedrainfall

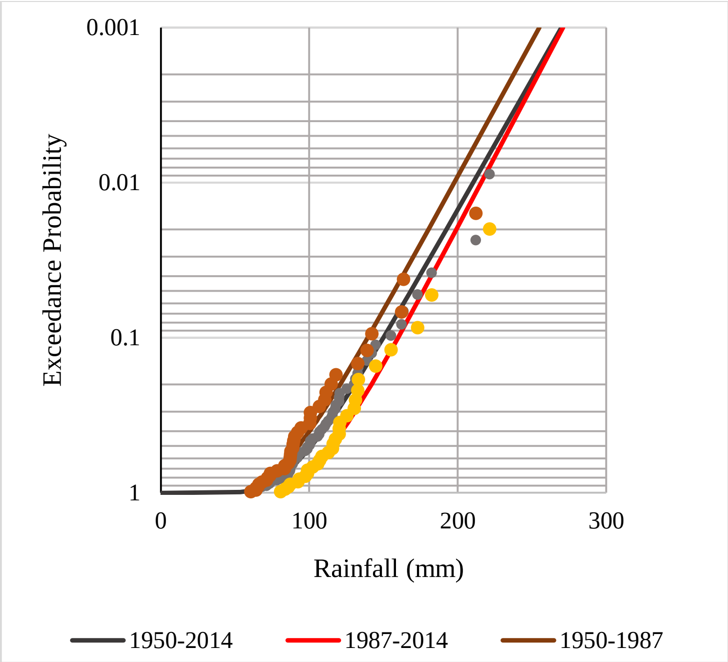


Figure 3.5 - Exponential Paper of Gumbel Distribution for 5- day accumulated maximum rainfall

Mikosz (2017) made a countrywide assessment on flood and drought disaster frequency based on the climate change projections of the Intergovernmental Panel for Climate Change (2013). The southern region is notably the one with highest expected increase in monthly average rainfall and as emphasized in the study is a relatively densely and developed part of the country. Leite (2016) studied the Itajai River basin and discussed the effects of climate change according to the Global Circulation Models (GCMs) and the International Panel for Climate Change projections (IPCC, 2013, 2014) and the alarming increase in rainfall that is expected to the southern region.

The results of the present study analysis reveals that the effects of climate change projections agree with the past climate change, registering an increase in both average rainfall amounts and in intensity of events, as the shorter duration accumulated rainfall display a higher change. This effect has a direct impact in the frequency and intensity of the extreme events.

Using the largest sample available is the most traditional way of statistically estimating the extreme flood events. For the calculation of the flood areas of Sao Sebastiao do Cai and Montenegro in the Rio Grande do Sul State, Brazil, CPRM (2016) considered the largest set of available data, and used sets of 69 and 77 years of historical data for calculating the return period of flood peaks. Read & Vogel (2015) discussed the reliability of usage of return period in non-stationary conditions; understanding the patterns of climate change is necessary in order to anticipate the hazard and prevent the damages in advance.

As table 3.1 shows, the calculation of extreme event probability density function is extremely dependent on the period of acquisition of the data set; therefore, the studies that present their calculations without specifying the period are difficult to compare.

Table 3.1 – Probability of Daily Maximum Rainfall

Return Period	A -1950 - 1987	B - 1950 - 2014	C - 1987- 2014	Increase A-C (%)
1000	90	104	111	23.36%
500	84	97	104	23.32%
50	67	76	82	23.11%
20	60	68	74	22.99%
10	54	61	67	22.87%
5	49	54	60	22.73%

Table 3.2 – Probability of 3 Days Accumulated Rainfall

Return Period	A -1950 - 1987	B - 1950 - 2014	C - 1987- 2014	Increase A-C (%)
1000	189	209	214	13.24%
500	177	196	201	13.71%
50	136	150	158	15.90%
20	120	132	141	17.20%
10	108	118	127	18.47%
5	94	103	113	20.17%

Table 3.3 – Probability of 5 Days Accumulated Rainfall

Return Period	A -1950 - 1987	B - 1950 - 2014	C - 1987- 2014	Increase A-C (%)
1000	250	270	271	8.22%
500	234	252	254	8.87%
50	178	192	199	11.93%
20	155	168	177	13.79%
10	138	150	160	15.63%
5	120	130	142	18.12%

The average monthly rainfall (Figure 3.5), seasonal change varies from a minimum of 133mm to a maximum of 177mm while average discharge changes from an average close to 1000 m3/s in the summer to 2000 m3/s in the winter, this relation might be explained by changes in evaporation. The south region is the coldest in Brazil, the changes in evaporation and possibly in vegetation growth across the seasons are an important variable that should be taken in consideration, omitting those parameters might lead to difficulty in calibration for longer periods of time, if the simulations are to be used to simulate near real time flood, the evaporation should be calculated for the exact period.

For effect of the simulation, the evaporation was calculated based on the difference in average monthly volume of rainfall and average monthly discharge; by this approach, the net volume loss due to the effect of infiltration to deeper aquifers is also diluted in the evaporation parameter. As the functionality of RRI software allows to simulate either lateral underground flow or Green-Ampt model infiltration loss to aquifer; the second was considered to be the best option, as total infiltration to the aquifer is unknown and the lateral water flow in the soil is an important component.

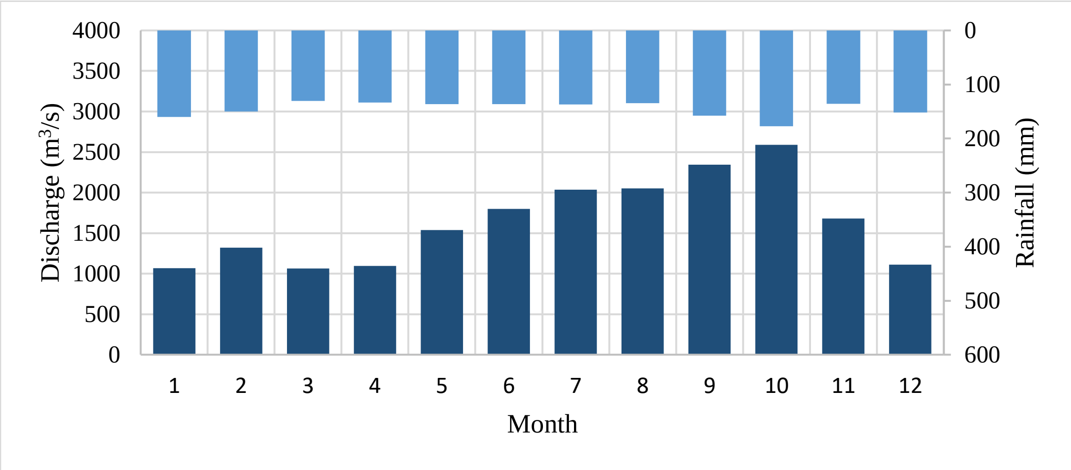


Figure 3.5 Relation of average monthly rainfall and discharge (1941 - 2014)

3.2. Design Rainfall for Hazard Map

The daily rainfall values, both for calibration and for rainfall design were transformed to hourly rainfall using the equations and set of rules as described in the JICA (2013); the result from this transformation is that instead of having the same value of rainfall for the whole day, the total value is distributed according to the rain of the two adjacent days, creating a peak effect that adjust better to the scenarios of the area, while preserving the total amount of rainfall, the application of the transformation improved the matching of time of peak discharge in the simulations.

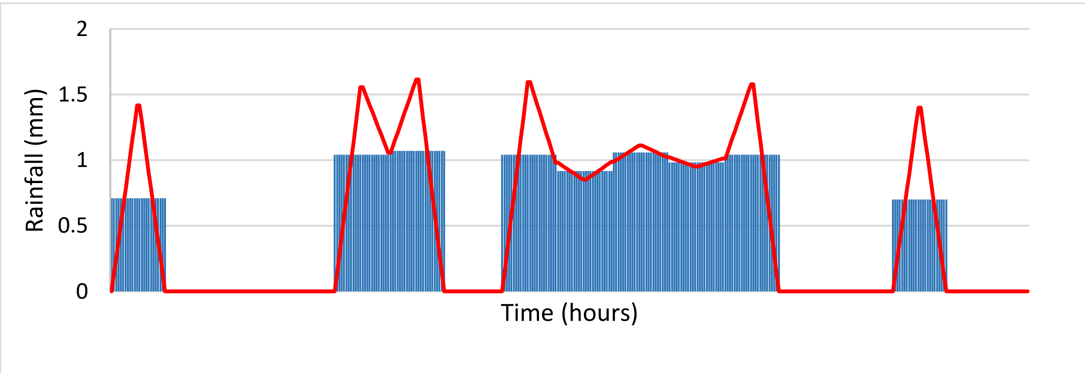


Figure 3.6 Example of results of interpolation of hourly rainfall values from original evenly distributed values.

For consideration of the temporal distribution within an event of designed rainfall, the four largest recorded peaks at IFS were identified, the events in August, 1965, July 1983, August 1984 and May 1995, the Figure 3.7 illustrates the normalized distribution of rainfall in the days after and before each historical event and the pattern used for the designed rainfall which is the average percentage of the normalized values.

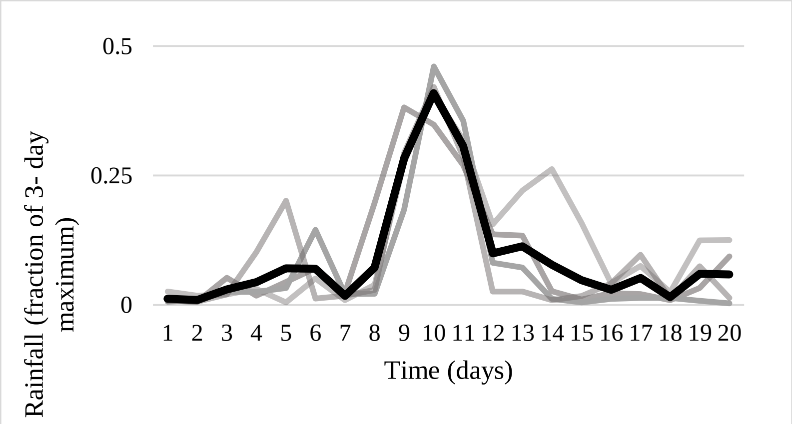


Figure 3.7 – Temporal distribution of historic events and design rainfall

3.3. Spatial Distribution of Designed Rainfall

The consideration of spatial distribution specifically for extreme events is important because it does not necessarily match the average rainfall distribution in the basin. For the spatial distribution of the design rainfall, the past events which surpassed the calculated rainfall for the return period of five years were selected, the relative amount of rainfall for each gauge in relation for the basin average in those events was calculated and the average values for each gauge that had ten or more day records was plotted with its respective geographical coordinates. From these values, a distribution map was then interpolated in ArcGIS using kriging 3.8, which was later converted to ASCII format with a resolution of 3km and used to multiply each hourly value for design rainfall.

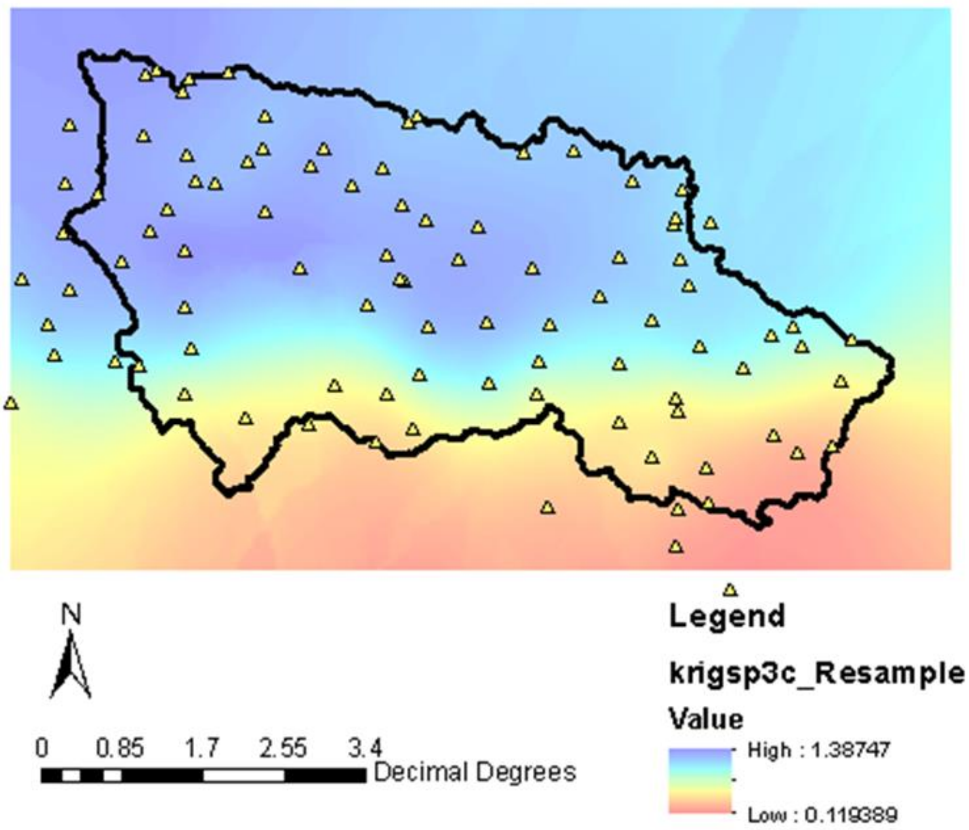


Figure 3.8 – Spatial Distribution of Design Rainfall

The design rainfall was then spatially distributed in the map using a tool developed in Fortran language, the result design rainfall was a *.dat* format input formatted to be used as direct input in RRI software.

4. HYDROLOGY

4.1. Models in Hydrology

The studies in hydrology require transformation of basic concepts in actual computable values, this process can be done in several ways; Jayawardena (2004) classifies the computational approaches in three types, conceptual models, physically based distributed models and black box models. Each approach has both vantages and disadvantages depending on each case; the author also discussed how data driven approaches has been changing the perspectives in hydrology.

In flood risk evaluation there are a few basic approaches on frequency of flood studies, one may study the extreme event frequency of either flood height, flow discharge or rainfall, in Brazil, the first approach was used by Vaz (2015) for the city of Porto Alegre for a simplified approach and focus on the architecture of urban planning , this approach has the limitations of not being able to consider certain changes in the hydrological system of the basin, such as land use changes, implementation of flood control structures and others, nor changes in the climate, such as increase or decrease in rainfall, evaporation, etc. In addition, working with extreme distribution of flow height itself has the limitation of not considering how discharge changes for each increase in water height, as the water overflows from the river channel to the flood plains, the characteristics of flood flow changes drastically, and those changes might be interesting to take into consideration for risk analysis. From this standpoint, working from rainfall and considering the whole process has many advantages, even though the process might be more complex.

In the past decades, many structures have been built in the rivers, according to the report from the Brazilian Committee on Dams – CBDB (*Comite Brasileiro de Barragens*, in Portuguese), representative of International Dam Committee – ICOLD Brazil has over 1500 large dams. When dams are not full, they usually operate holding the maximum amount of water possible for future energy generation, releasing the minimum designed discharge. Therefore, the smaller discharge peaks can be held within the reservoirs. Due to this activity, the hydrological pattern of the basin is changed. Hu (2008) studied in detail the changes in the hydrological system of the Huaihe River Basin, in China, which have several reservoirs and sluices, and identified a significant change in the discharge characteristics. In case one works directly with discharge or flood height for risk analysis, some attention would be required to avoid misinterpretation of the variability of the channel flow.The effects of the change in average, maximum and minimum discharge of rivers range from ecology to sediment transport; the extreme value analysis rely on the variability of the events.

Using the rainfall data has an advantage in this aspect, but the effects of the dams should also be considered in the hydrological simulations, if the information is available, the usage of complete hydrologic-hydraulic simulations can include simulations of change in rainfall pattern, in land use and also other flood prevention works along the basin.

Several computational tools are being currently applied in hydrological models for disaster management studies. To understand the capabilities and limitations of each model is fundamental when judging the efficiency or performance of each model based on the application of the results. The hydrological system can be quite complex and the models are usually not designed to simulate all the processes.

One of the difficult systems to integrate to hydrologic models is the underground water flow; the aquifers may have great complexity and both acquiring information and translating them into computable processes can be quite difficult. Gusyev (2016) demonstrated the time of transit the water might take underground can reach several years, this type of slow flow is important for maintaining base flow of the rivers and might affect also soil moisture and therefore, hydraulic conductivity changes after periods of drought.

Collodel (2009) discussed how the increase in discretization in distributed models lead to an increase in complexity and computational requirements for calibration in a study using the Storm Water Management Model (SWMM) in Brazil. CPRM (2004) has used the HEC-RAS software for mapping the flood prone areas in the city of Governador Valadares, in Minas Gerais State, Brazil

4.2. Model Preparation and Calibration

The hydraulic hydrologic model in the RRI software can be understood as a physics based model as it calculates the water flow by solving the mass conservation equation and momentum equation, considering physical parameters such as gravity, water density, Manning's roughness in a diffusive wave approximation of a gradually varied steady flow. (Sayama, 2015) The manual describes a range of acceptable values for parameter setting, the values suggested are those which represent similar range to the parameters that can actually be measured in field, however, the values were optimized to obtain a better adjustment to the simulated and observed discharge, in an attempt to compensate other distortions in the data such as topography or river shape and size.

The RRI software has a feature for estimating river width and depth, however, for increase in accuracy another approximation for real parameters was made. First, a set of width measurements using satellite imagery using Google Earth, the point measurements were interpolated to lines and further to images in ASCII format.As detailed data on width and depth is limited, small variations in river width were neglected.

The depth was estimated by using a sample of measurements from seven river cross sections from fluviometric stations from ANA, the measured width and area of the section was used to estimate a mean depth in a rectangular shape approximation, a regression logarithmic curve was adjusted to estimate the depth in the range of measurements previously mentioned (Appendix A.1).

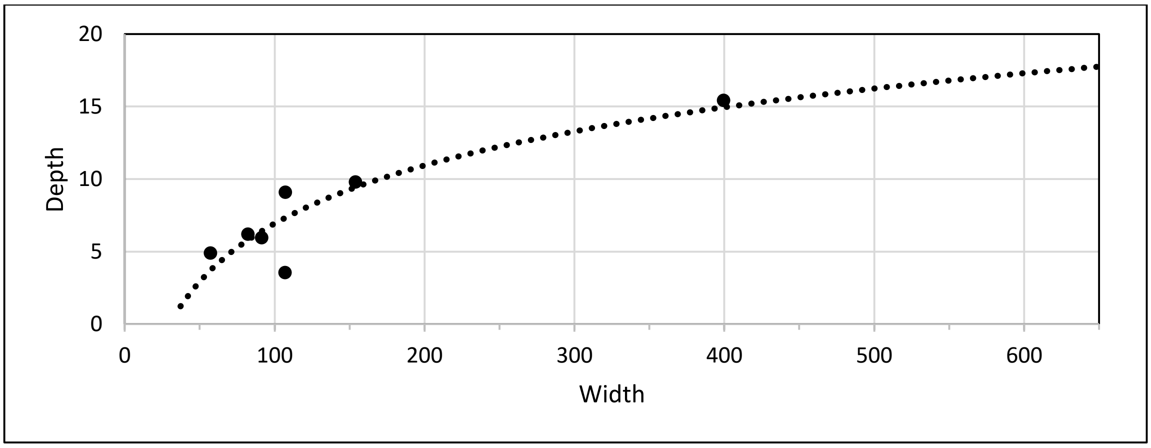


Figure 4.1 – Depth x Width Function for river dimension estimation

One possible problem of using low resolution, such as 3km pixel, is that the terrain is smoothed, meaning that the slope declivity is reduced; therefore, when using lower resolution models, the parameters measured in field and representative of real conditions, no longer can simulate the runoff process.

However, modelling large basins in high resolution requires much more computation time, and eventually might not be feasible from a practical stand point. Therefore, considering alternatives becomes interesting when considering a methodology for ample usage.

One alternative when preparing a hydrological model would be to test the available equipment and decide the maximum resolution that can be used for running the simulations within acceptable time. But for the purpose of this study, the possibility of running two simulations in different spatial resolutions was chosen as it might be an alternative to approach higher resolutions in very large basins; the first model, further referred as Discharge Hydrological Model was prepared with a spatial resolution of 3km and was used to calculate the Discharge of main rivers within the whole Upper Uruguai River Basin; after calibration the calculated discharge for each simulation is used as a input value of boundary condition for the second hydrologic model, further referred as Flood Hydrological Model, which included the smaller basins around the target area, the municipality of Irai-RS.

Both models were prepared with topography from the the Topodata project (Valeriano, 2005) which is a post processed data in a spatial resolution of 30 meters that prepared from the original SRTM data using the process described by Valeriano (2005, 2009). While some option, such as the Advanced Land Observing Satellite (JAXA, 2008) provides higher resolution data, the additional time that it would be spent on preparing the mosaic for the whole basin, and the size of the files itself made the Topodata a better choice in terms of time and processing capacity for the present study; even though the use of higher resolution data is expected to improve the results if further analysis is to be taken.

The DEM was upscaled to 3km pixel size using the aggregate function from ArcGIS. The RRI package itself provides a tool for downscaling a method which preserves the hydrological properties of the terrain according to the guidelines provided by Matsutani (2006), however the process could not be successfully applied in the original data due to lack of processing capacity; the possibility of testing better equipment for this step was not exhausted and further effort could be done to attain optimal results. One possible solution is to this smoothing effect is to replace certain parameters in order to compensate the slower runoff, which rendered good results.

The period for calibration was chosen as the flood of September 1961; the choice was based on data availability for the station closest to the target area, as the basin at the present moment has several minor and major dams, it is desirable to calibrate the parameters using data from before the construction of the dams, so the interference of them can be discussed by simulating similar events after the construction, but also a similar number of rain gauges should be available for all simulations, to reduce the effect of different rainfall sample sizes.

The Discharge Hydrological Model was calibrated using the discharge record from the station 74100000 - Irai (ANA, 2017). For evaluation of calibration of the discharge model both Nash Coefficient Value and matching of peak was considered, as the measurement of discharge is in daily values and the model outputs are in hourly values, for computation of Nash Coefficient value, the output of one time step for the time equivalent of 12:00 was used for comparison to measurement value.

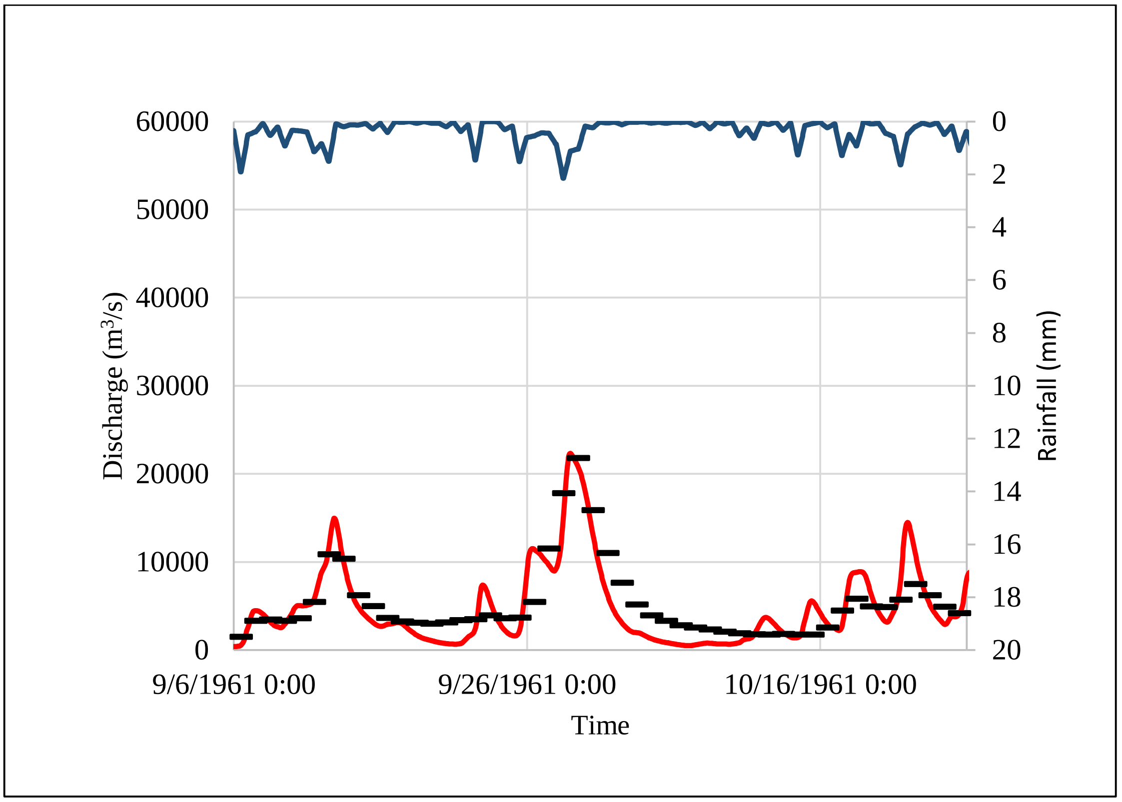


Figure 4.2 Hydrograph of historic event of September 1961 measured and simulated for calibration

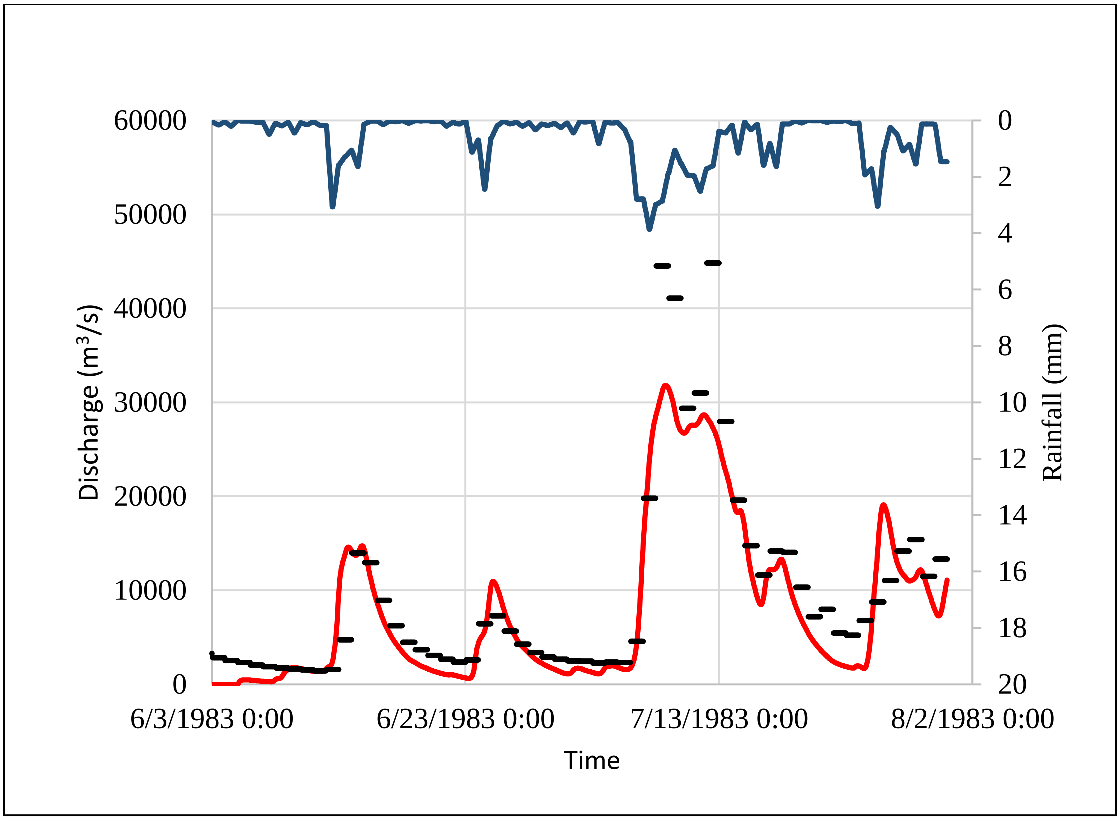


Figure 4.3 – Hydrograph of historic event of June 1983 measured and simulated for validation

After Calibration of the discharge model, the designed rainfall for each return period was simulated and the outputs of the two major rivers that could be simulated in the Discharge Hydrological Model were used as a boundary condition of input discharge in the Flood Hydrological model.

The Flood Hydrological Model was prepared with a DEM of 300m pixel size before upscale the DEM, another hydrological tool was used to improve the fidelity of the simulation to the real conditions, the tool developed by Jackson (2013) provides a balance between cut and fill when preparing the DEM for hydrologic simulations by using the procedure described by Soille (2013).

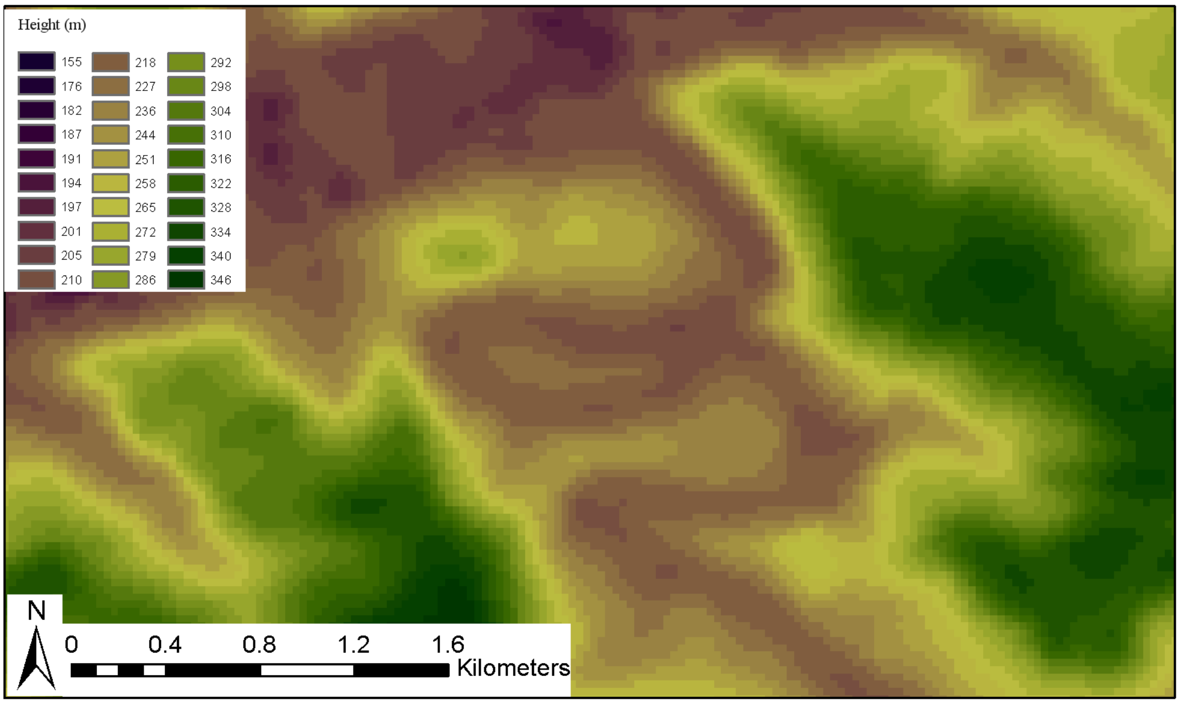


Figure 4.4 – Original DEM (Topodata – Valeriano, 2005)

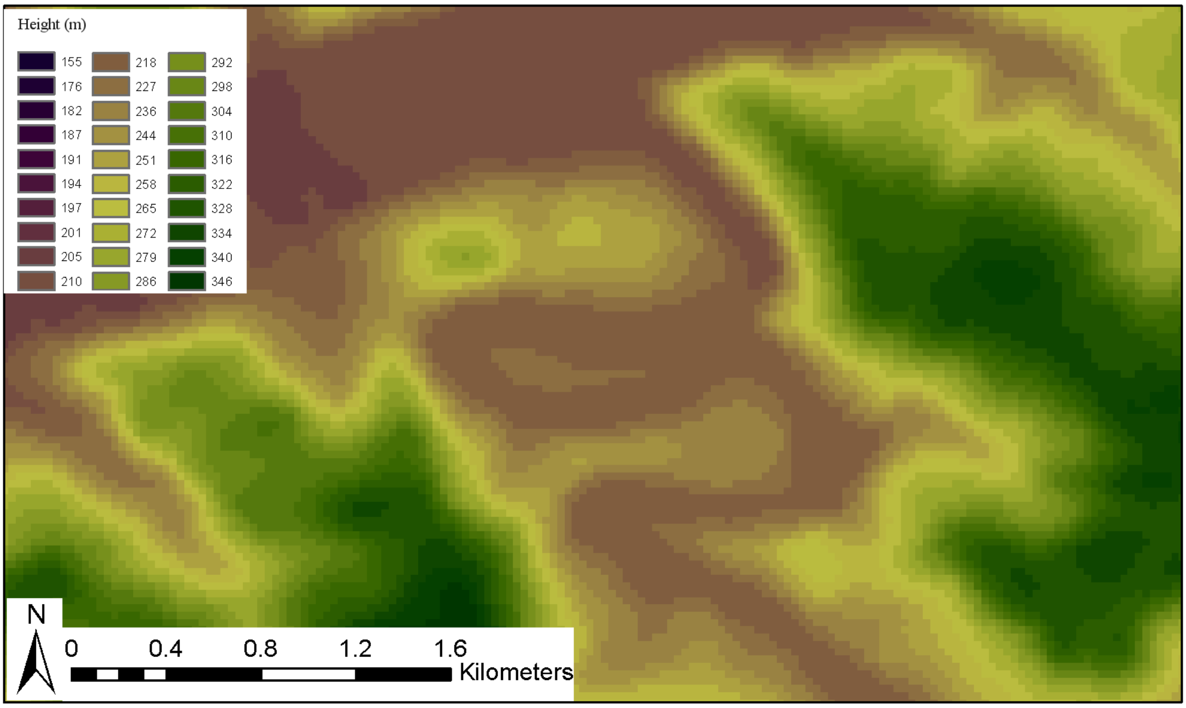


Figure 4.5 – Result of hydrologic correction tool *Fill* in ArcGIS

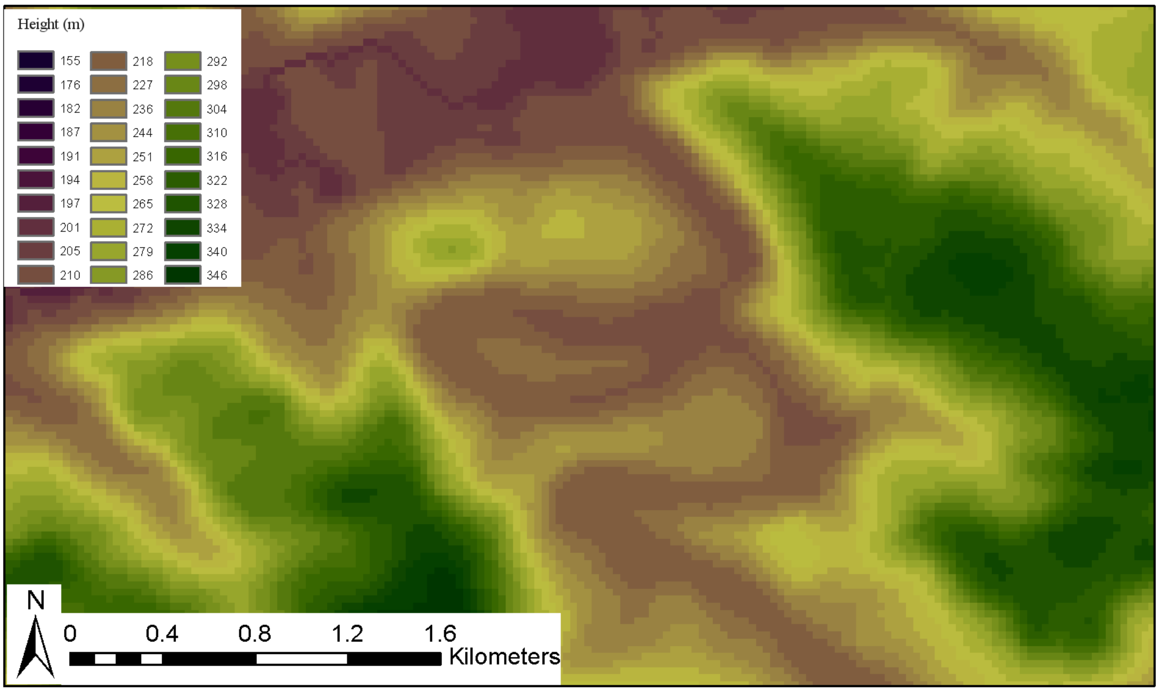


Figure 4.6 Result of hydrological correction by Optimized Pit Removal Tool (Jackson, 2013)

The model was then upscaled to 300m using aggregate function of ArcGIS with minimum value of surface, in order to represent the real height of valley bottom, the raw results of the simulation were post processed by using Raster Calculator Function to calculate the absolute height of water by subtracting river depth from water level and adding the absolute value from downscaled topography; from the result a point vector data was extracted and an envelope surface of absolute water height from river was interpolated using inverse distance weight (IDW) method. The result was intersected with the 30m resolution DEM to produce a 30m resolution map of flood extent.

For validation of the approach, the event August 31st of 2011 was simulated and the results were validated by comparing the flood extent of the simulation and the images of the Landsat 7 (NASA, 2011); the original images for bands 3, 4 5 and 6 were reclassified using Iso Cluster Unsupervised Classification, with 60 classes later interpreted in either land, water or noise.

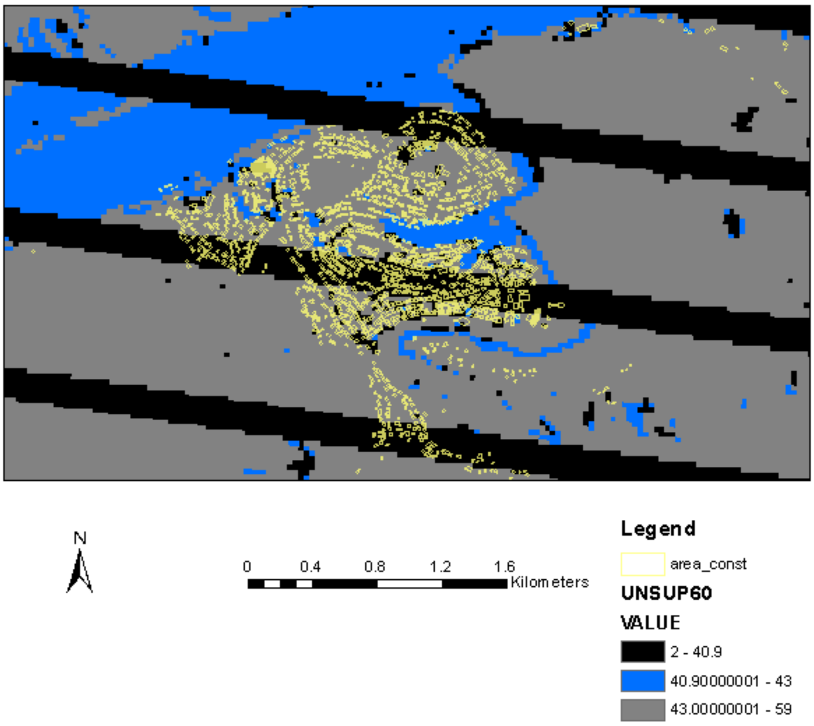


Figure 4.7 – Isocluster unsupervised classification of Landsat image -2011 flood event

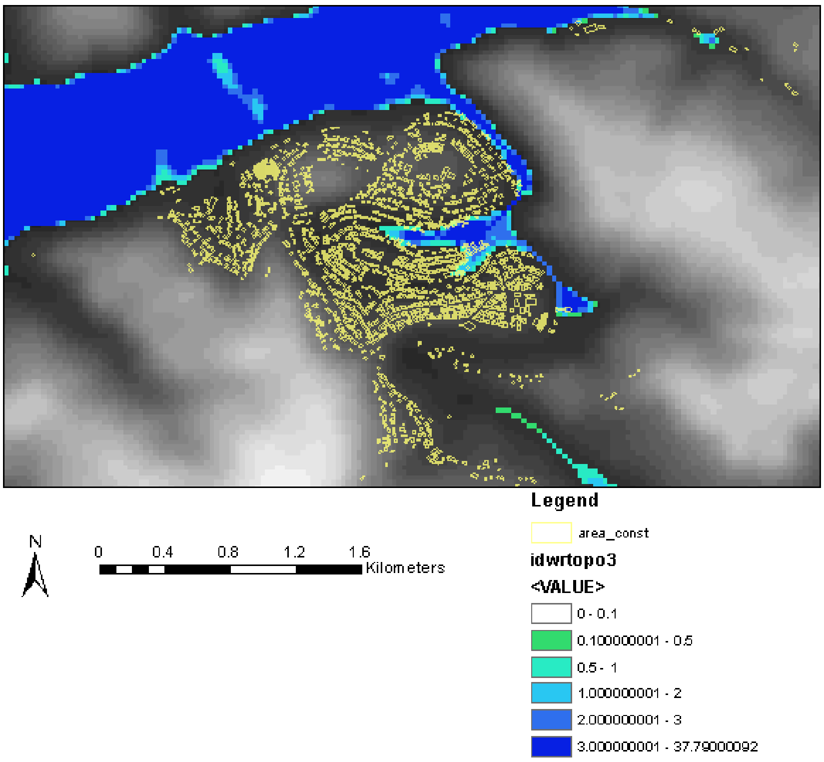


Figure 4.8 – Results of simulation for 2011flood event.

4.3. Flood Hazard Simulations and Map

The design rainfall for each return period was used to model the flood affected area, each return period was simulated in the Discharge Hydrological Model and in the results were used as boundary conditions for the Flood Hydrological Model. The results are presented in Appendix A3.

5. FLOOD DAMAGE FUNCTIONS

5.1. Flood damage functions in the literature

The damage caused by floods can be divided in tangible an untangible, the tangible damage can be directly represented as monetary loss from direct and indirect damage caused to residences, business establishments and infrastructure. Intangible damage is that caused by deaths, trauma and others that cannot be directly measured as monetary damage (Lekutai, 2001). The UNISDR terminology for disaster risk reduction (2009) do not define the concept of tangible and intangible damage; while later update (UNISDR, 2017) define that indirect damage might me intangible; human assets are defined also as tangible in the definition of exposure in this guidelines.

The flow velocity should also be considered for damage calculation (Moel & Aerts, 2011) and duration of flood as in Veerbeek & Zevenbergen (2009), MLIT (2005). Bremond (2013) made a review of methods for agriculture damage evaluation and considered other factors that should be included in the damage curves, such as flood duration, velocity, contamination, salinity.

Roos (2003) provided a comprehensive deterministic approach on the damages caused to buildings by flow velocity during floods in Germany and Netherlands, based on horizontal load applied to structures, describing a model in which depths below 0.5 meters would require an unrealistic velocity to damage walls, and for increasing water depths a start to damage and complete damage of walls was defined, the study was developed to fit the context of breach in levees in the Netherlands context.

Clausen & Clark (1990, apud RESCDAM, 2000) on the other hand described damage to building structure with a threshold of minimum depth, regardless of velocity; the case study of dam or levee failure brings different perspectives of flood flow from the natural generated floods, although flash floods might also develop high velocities and destruction capacity.

Other authors also use flow velocity as determinant in risk levels, Cançado (2008), used the guidelines from Federal Emergency Management Agency (FEMA, 1979) as measured in the Sowashee Creek, United States of America to evaluate the potential flood damage in the municipality of Manhuaçu in Minas Gerais State, Brazil.

Brouwer et al (2007) investigated the relations between socio economic profile and the exposure to flood risk and found interesting good correlation of flood depth to the household income level, revealing quantitatively a clear social segregation that pushes poorer people to the flood prone areas.

One of the most used database for flood damage in recent studies in Brazil comes from the 2000 flood in the city of Itajubá, Minas Gerais State, the specific event was studied and described in many studies. Figueiredo (2003) used satellite imagery and topography data to delimitate the flood impact area. A survey on both the households and economic sectors was widely explored by Machado (2005), Nascimento et al (2007), Cortes (2009) for development of flood depth damage curves. Those studies also provided the data further used for the Global Depth Damage Curves proposed by Huizinga (2017).

One important element when interpreting the information on the studies are the conditions of the flood and the city; flood depths up to 3m were registered, which coincides with the common ground floor height in Brazil; this implies that all damage curves tend to stabilize at maximum damage at the height of approximately 2,8m. Also to consider, the city of Itajubá has a population density that is observed in countryside cities, whose population is smaller than the largest metropolitan area. Those conditions and characteristics of the flood event and location set limitations on the interpretation of those curves; if flood depths larger than 3m occur it is expected that the damage will continue to increase for all buildings with more than one floor.

Jonov et al (2013) made a study on the relation between flood depth and damage for the structure of buildings in the city of Belo Horizonte – Minas Gerais State, Brazil and also found discrepant damage between the poor households and common households, describing the pathological effects from the structural point of view and giving detail in the activities and costs that would be involved in repairing the damage. Canholi (2005) and Tucci (2007) pointed the damage cost assessment as the most difficult task in using a hydrological model and damage curve on flood risk analysis; as the acquisition of the ideal data that is traditionally used in this type of study is consumes money and time. Vaz (2015) used currency and inflation correction and urban growth to estimate the damage for events of the same dimension of past events would repeat, based on flood damage records in the city of Porto Alegre, Rio Grande do Sul State, Brazil.

While a conventional approach is to deal with human damage as an intangible asset, some authors also propose measurable damages to human life. Lekutai (2001) proposed the conversion of anxiety damage to production losses, to estimate the psychological effects of flood disaster in a comparable measure; the author emphasizes the importance of such estimations when considering feasibility analysis. In a different approach, Yokomatsu *et al* (2013) evaluated the human losses and affected people in a monetary measurement by interpreting the effect of disasters in the economy through a Cobb Douglas type production function, in a different interpretation, the study considered the modified Solow Model (Mankiw, 1992)(Equation 5.2) and utilized affected population and mortality rate for parameterization of for Human Capital in order to calculate the reduction in production of each region caused by the floods.

5.2 Approach on Flood Damage

The present study evaluated the flood damage by applying the normalized flood depth-damage curves from Huizinga (2017) into the simulated flood height and intersecting the damage raster to the urban percentage raster and agriculture percentage raster, from this point a few ways to calculate which maximum damage to apply, as illustrated by Figure 5.1.

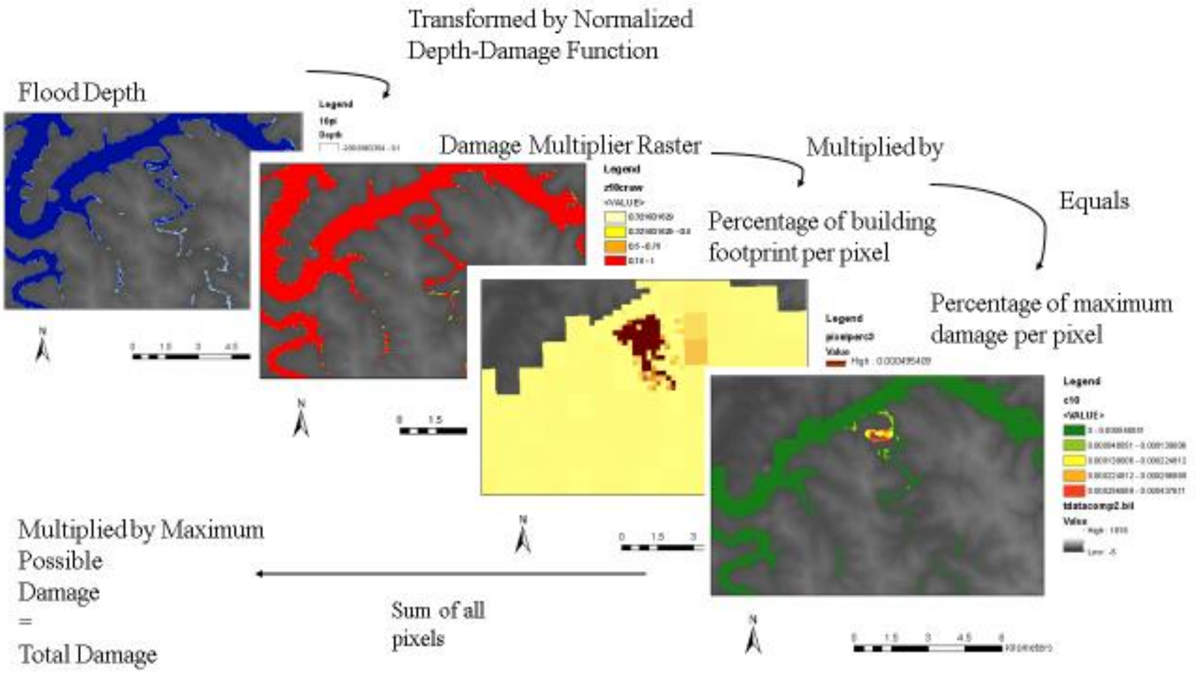


Figure 5.1 – Organogram of damage calculation process

For the estimation of maximum damage, two approaches were conducted, the first is the one presented in by Huizinga (2017), the method presents an optional 60% reduction due non-damageable parts in masonry buildings, that was considered separately, the method was applied both using country GDP and municipality GDP, the results are summarized in table 6.1.

For estimation of built area, the building foot print area delineated was used, with 357,000 m^2 the residential area was estimated with the average dimensions per social class reported by Machado (2004) according to the number of households per social class obtained in the Census (IBGE, 2010)

From the understanding of flood damage of economy sectors as a share of the capital stock (MLIT, 2005), the possibility to use this relation to approach the damage caused by floods was investigated. The manual describes the guidelines for calculating indirect flood damage by calculating the reduction in productivity by subtracting the direct damage from the capital in a Cobb Douglas type production function. As the following:

$$Y = AK^{\alpha}L^{\beta}$$

Equation 5.1 – Cobb Douglas Production Function

Where K is the capital stock of the company minus the value of the direct damage, A is the factor of productivity, L is the labor, α is the capital share of output and β is the labor share of output.

If the human capital can be expressed as the efficiency of the workforce, from the understanding of the parameters used in the modified Cobb Douglas type production function proposed by modified Solow model by Mankiw (1992) it could be expected that highly developed sectors or activities would rely on relatively smaller capital inputs for production output. The less developed activity on the other way rely basically on the input of capital to generate production, as their human capital value would be smaller.

$$Y = K^{\alpha} H^{\beta} (AL)^{1-\alpha-\beta}$$

$$Y: Production$$
$$K: Capital$$
$$L: Labour$$
$$A: Production\ Factor$$

Equation 5.2 – Modified Solow model production function (Mankiw (1992)

In this sense, a comparison between high value human capital and low value human capital type of activities could be conceptually done for an example: even though an architecture office would have a capital value representing the market value of such office, the physical assets themselves would represent a much smaller part when compared to a Laundry service, where the employee adds less to the revenue when compared to the physical assets themselves, even though the capital value of the said business in terms of pricing of the company would be high due to the high value of physical assets.

The data of the damage caused by the 1967 flood in the city of Porto Alegre, was acquired by the extinct National Department of Public Works and Sanitation (DNOS – *Departamento Nacional de Obras e Saneamento*, in Portuguese) and later studied by Vaz (2015), which adjusted the currency to 2014 and considered urban expansion.

The report from DNOS (1968) damage survey gathered information of number of establishments, number of employees, total revenue, value added and damage caused by the flood (Appendix A.4) the establishments were divided in 107 categories from industry, services and commerce. The data was investigated, and by dividing in one category as Industry&Services and another for Commerce and plotting both the ratio of production per employee in an axis and damage as a fraction of the revenue in the other axis, an interesting distribution was found (Figure 5.2 and 5.4); also, the value added per employee and the damage as a fraction of the total revenue presented a correlated distribution (Figure 5.3 and 5.5).

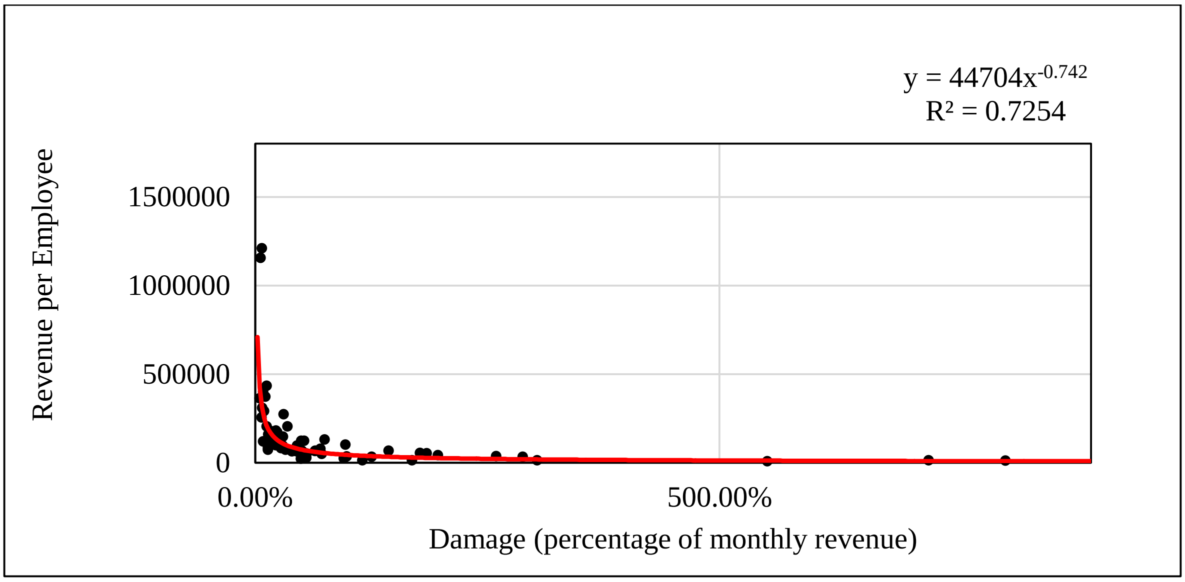


Figure 5.2 - Relation between damage and revenue per employee for industry and services 1967 Porto Alegre flood event.

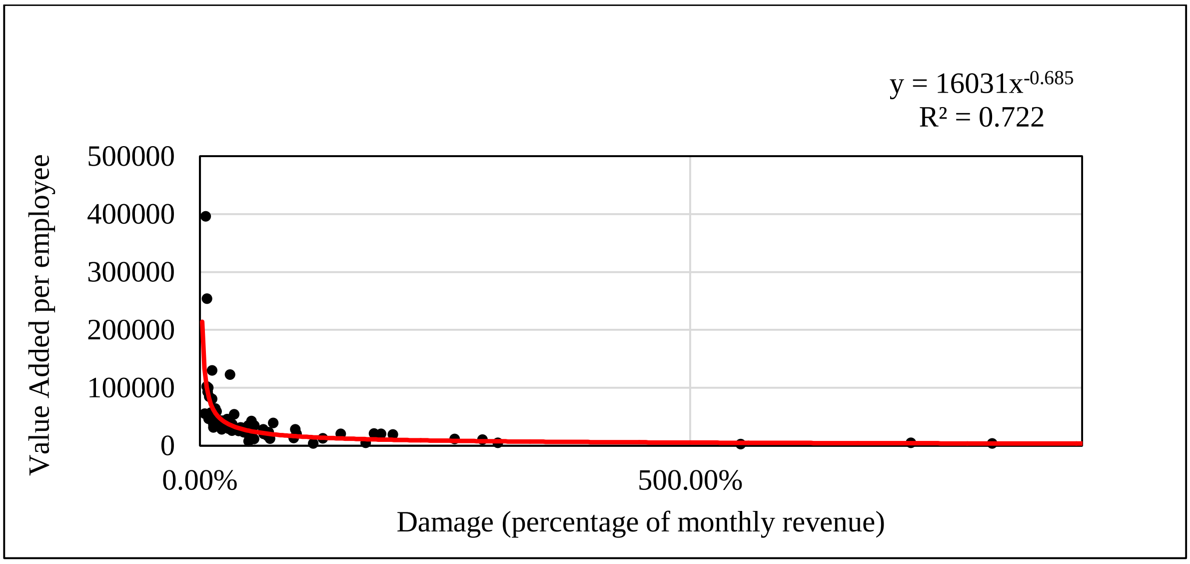


Figure 5.3 - Relation between damage and value added per employee for industry and services 1967 Porto Alegre flood event.

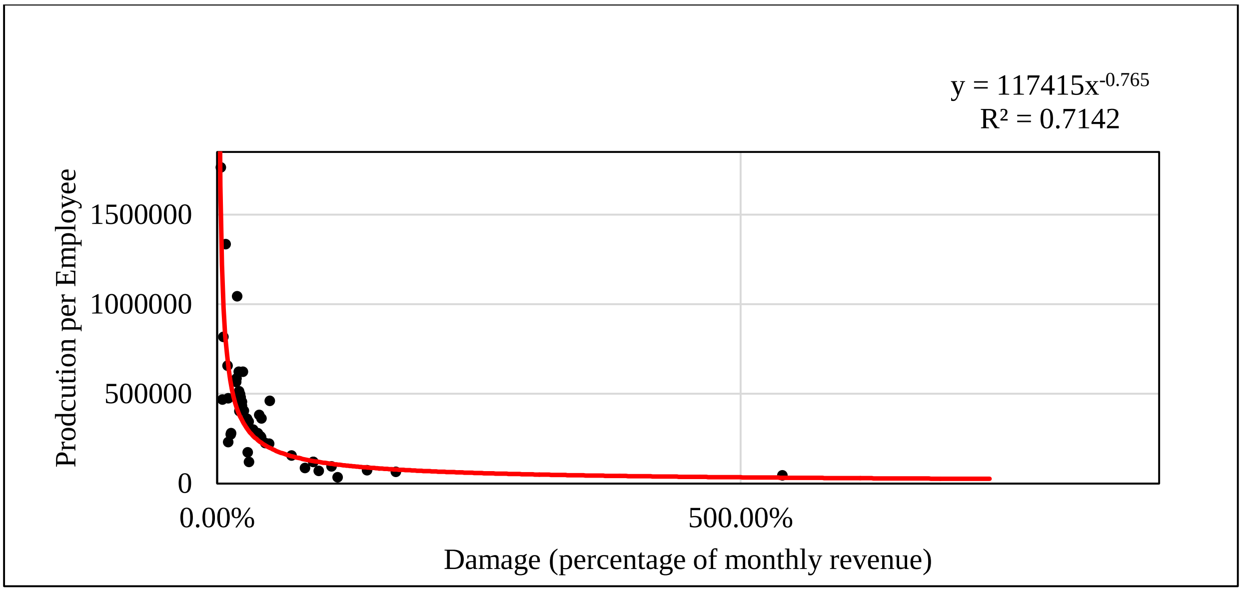


Figure 5.4 - Relation between damage and revenue per employee for commerce 1967 Porto Alegre flood event.

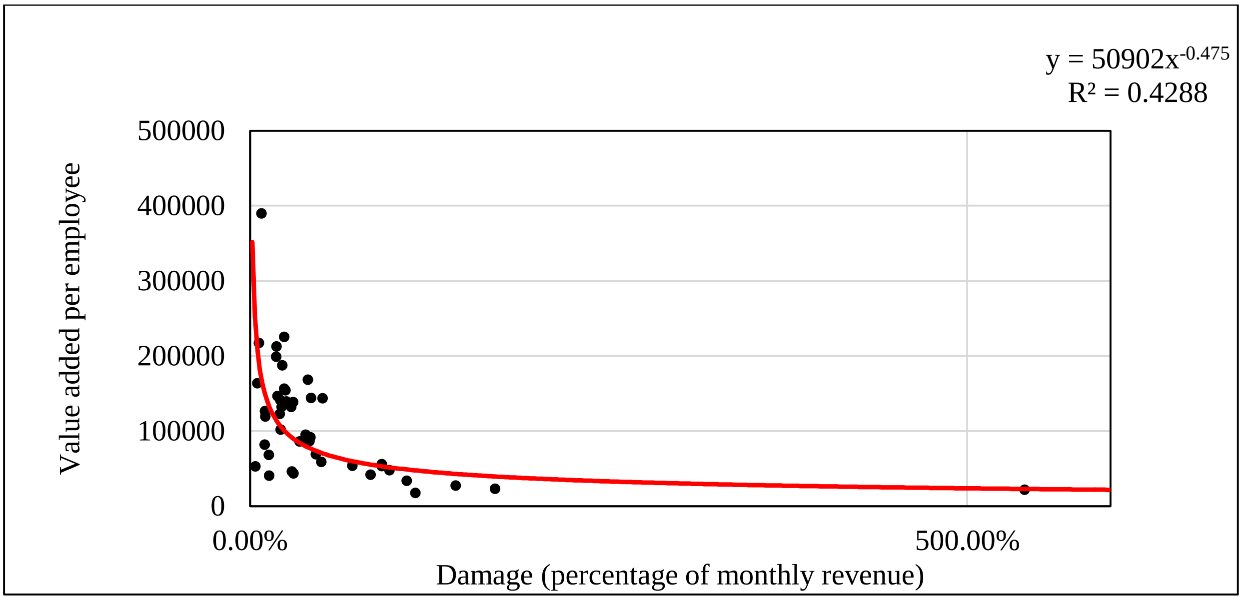


Figure 5.5 - Relation between damage and value added per employee for commerce 1967 Porto Alegre flood event.

Theoretically, this distribution can be explained by the parameters that control the economy production as proposed by Mankiw (1992), the production is the result of labor usage of physical capital, human capital and the productivity factor, but from the understanding of damage of property and goods as a damage of the physical capital itself (MLIT, 2005) we can understand the maximum flood damage of a sector as the damage to their physical stock of capital in a time interval as short as the flood event itself.

The high revenue activities rely on a large sales amount and consequently are expected to have very fast rotation of sellable goods, the instant damage caused by the flood therefore, is relatively small when compared to the total annual or monthly sales; some categories that were found with this characteristics in the flood damage of 1967 are fast stock rotation of highly perishable goods such as categories of eggs wholesales and fresh meat on the other hand magazines are likely to be expensive and have a smaller sales speed, some magazines might sit on a shelf for a long time before being sold and have a good profit margin when sold.

The function observed in Figures 5.3 and 5.5 show that higher value added per employees is also related to smaller damages, this can be understood as because very high capacitated workforce are able to generate value added from smaller amount of physical capital, which is lost during flood.

The considered concept of capital for this study is then both the fixed built capital (such as building, furniture, electrical and electronic equipment, machinery, etc), and instantaneous rotation capital (such as stocks of products, raw materials, etc). Other aspects of capital are in this interpretation are considered a part of the productivity factor and human capital (copyrights, brand value, technological development, etc). As for Human Capital, in this study is considered as the productivity increase due to human development, in this case represented by the value added per employee, even though it is understood that this parameter is also influenced by advanced technologies and modern equipment that is included in the capital parameter.

Similarly, several of flood-depth damage curves were developed for the city of Itajuba published by Machado (2005), Nascimento (2007), Cortes (2009), also show very discrepant damage per meter square for bookstores in opposition to construction material.

In this understanding an approach for development of a function to calculate maximum direct damage according to the econometric parameters of each economic sector was developed based on the data from DNOS (1968, apud Vaz, 2015). Firstly applying a natural logarithmic transformation to the values of revenue per employee and value added per employee, the damage was normalized as damage divided by monthly revenue (revenue divided by 12) and multiplied by 100 to prevent values smaller than one, and also applied the natural logarithm transformation; then, using the Microsoft Excel tool for data analysis a multiple linear regression was successfully obtained (Equation 5.3 and Table 5.1) with a range of acceptable correlation and error (Table 5.2). Finally, the equation 5.3 was obtained for the estimation of the maximum damage.

$$D_{Max_i} = Exp(x_1 + x_2 * LN(V_e) + x_3 * LN(R_e))$$

Equation 5.3 Maximum Damage Calculated from econometric parameters

Where D_{Max_i} is the maximum damage for a category as normalized percentage of the monthly revenue, V_e is the value added per employee, R_e is the production per employee, x_1, x_2 and x_3 are the weight factors. The values of x_1, x_2 and x_3 were calculated both for the local currency of 2014 and corrected to 2010 values with IGPD-I inflation index, as the following table, and divided in two categories, commerce and industry and services.

Table 5.1 Parameters used for calculation of damage based on revenue and value added

Variable / Cat,& Period	x_1	x_2	x_3
Industry & Services (2010 – R$)	14.9621953	-0.518946107	-0.518846943
Commerce (2010 - R$)	14.56687373	0.199408376	-1.066088576
Industry & Services (2014 – R$)	14.86605745	-0.518946107	-0.518846943
Commerce (2014 - R$)	14.48658723	0.199408376	-1.066088576

Table 5.2 – Adjustment and error of the function into 1968 flood damage data

Correlation Damage Calculated / Damage Measured	
Industry & Services	Commerce
0.80657629	
RMSE	
90.03874376	57.88114573
Average OBS	
89.00105045	53.45239856
Average Calculated	
77.71311833	48.86719771
Minimum Observed	
4.882376474	3.818115731
Minimum calculated	
3.082635478	4.407451853
Maximum Observed	
808.135777	540.1263364
Maximum calculated	
561.5989476	249.1722721
NRMSE	
0.112092577	0.107925151

Once that the alternative of calculate maximum damage as a function of those parameters seemed feasible, for the estimation of the maximum damage for the case study, the parameters of production per employee and value added per employee were therefore needed to estimate; as it follows.

5.3 Estimation of Socio Economic Profile

Considering the estimation of the econometric parameters that are used in the Cobb-Douglas production function, a review of previous researches revealed the potentialities and difficulties of each alternative. One alternative in this sense would be to approach directly the stock of fixed capital, as some publications have already approached this subject. Morandi (2004, 2016) and Silva Filho (2001) have used the Perpetual Inventory approach to calculate the stock of physical stock from the National Accounts (IBGE, 2015), however, the results are not suitable for disaggregation for the several economic activities that were targeted and from country to municipality, crossing the data from the National Accounts with the Industry Relations Table it was possible to identify that this disaggregation was done based on their own elaboration method and that several economic sectors were left with no register of increase in fixed capital. This also relates to the actual concept of capital that was then adopted for the release of those statistics, which for an example, do not consider the intermediary consumption of vehicles by the Transportation Services Sector as an increase in capital, even though some might argue that in this case the vehicle itself was being transformed from product to capital.

If the previously mentioned estimations for the physical assets would be remade considering those kind of increment, also the deprecation rate applied should be differently calculated for each one, as is hardly acceptable that a vehicle in intense use would be as small as 5% per year or 3.5% a year as it was applied in those studies for the fixed capital. Additional consideration on how to determine if an item of capital is considered as rotation capital or fixed capital should be taken then as some assets are replaced in a much shorter time than buildings or other assets.

Oliveira (2006) used number the study years as proxy for Human Capital when adopting the Cobb Douglas type modified Solow equation (Mankiw, 1992) for studying the relation of economic growth and equity in the State of Ceará, Brazil. Which revealed a good correlation between human capital and income per capita. Oliveira (2006) also pointed out the underestimation of the number of workers in the RAIS data and described the adoption of tax data as a tradeoff of losing sampling size in order to have a data with good confidence of not overestimating workforce.

The Locational Quotient method used with the data from the taxes from RAIS as described in the methodology proposed by Brene (2013) have proved efficiency for regional studies and , but when used in a scale of municipality, some issues might occur in specific sectors due to sub-sampling of such sectors.

$$X_i^M = \left\{\left(\frac{N_i^M}{N_i^{RPC}}\right)\left(\frac{W_i^M}{W_i^{RPC}}\right)\right\} X_i^{RPC}$$

$$LQ_i^M = \left[\frac{X_i^M / X^M}{X_i^R / X^R}\right]$$

LQ : $Locational\ Quotient$

N : $Number\ of\ Employees$

i: $Sector\ of\ Economy$

X : $Gross\ Product$

W: $Wages$

M: $Municipality$

R: $Region(Country)$

Equation 5.4 – Location Quotient

The Locational Quotient Method relies on the relative proportion of workers and average income to estimate the GDP distribution of a locality, when the first uses to use the technique to estimate the municipalities economies in Brazil, there was no other available data other than the RAIS tax data, as of the present moment the Municipality GDP is been published, still the data does not contain the same detail amount available in the data from the taxes.

One problem of using the Locational Quotient based on this data on smaller economies is because it is not possible to calculate it when the input number of workers is zero, also an unrealistic very small amount of workers might lead to drastic changes in the results, a municipality with four registered workers would have four times more production than a municipality with one registered worker.

Ramos & Ferreira (2005) studied the spatial distribution of the informality in relation to formal work in Brazil, the results showed that the average informality ranges from 40% to 70% in the Brazilian States.

The area of the case study is no exception to this pattern, the Figure 5.6 shows the distribution of labor force per activity from the RAIS data and a comparison with the municipality GDP, for the municipality of Irai-RS one of the aspects that stand out is the almost absence of workers in the agricultural sectors in the numbers provided by the taxes. This reveals that not only the taxes provide an underestimate number, but also that the sampling is heavily biased, while some activities register almost all their workers, other do not register at all. In the year of 2010, only in Rio Grande do Sul State, 30 municipalities didn't registered any worker in the agricultural sector, while in the Municipality GDP the minimum value added per municipality in the state was R$410,000.00, or nearly U$ 100 thousand per year.

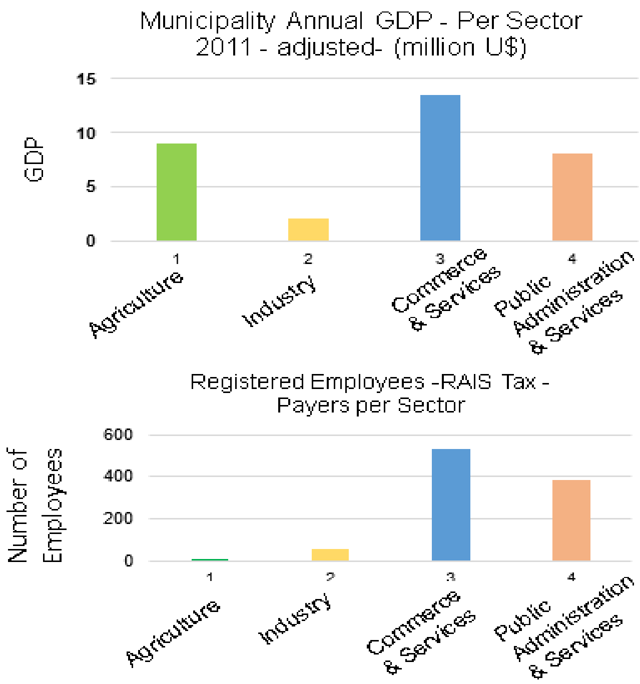


Figure 5.6 - Diference in the proportion between production and number of employees in tax data (Ministry of Labor, 2017, IBGE, 2016)

A review of the available official statistics that have been published reveals each type of qualities and disadvantages that each data can provide, which are briefly summarized in Figure 5.7, which also contains the period of research. The National Household Sampling Research (*Pesquisa Nacional por Amostra de Domicílios*, IBGE-PNAD, 2016) provides good overview of workforce distribution in each sector, the sampling size is smaller than the Census research as unbiased, as it has a wide distribution, the disadvantages of this research is that the sample size is not as large as in the census and the level of detail is also smaller than the tax payments. The CENSUS data (IBGE, 2010) was built on an immense sample size, therefore the accuracy of the data is considered as true data in this research,

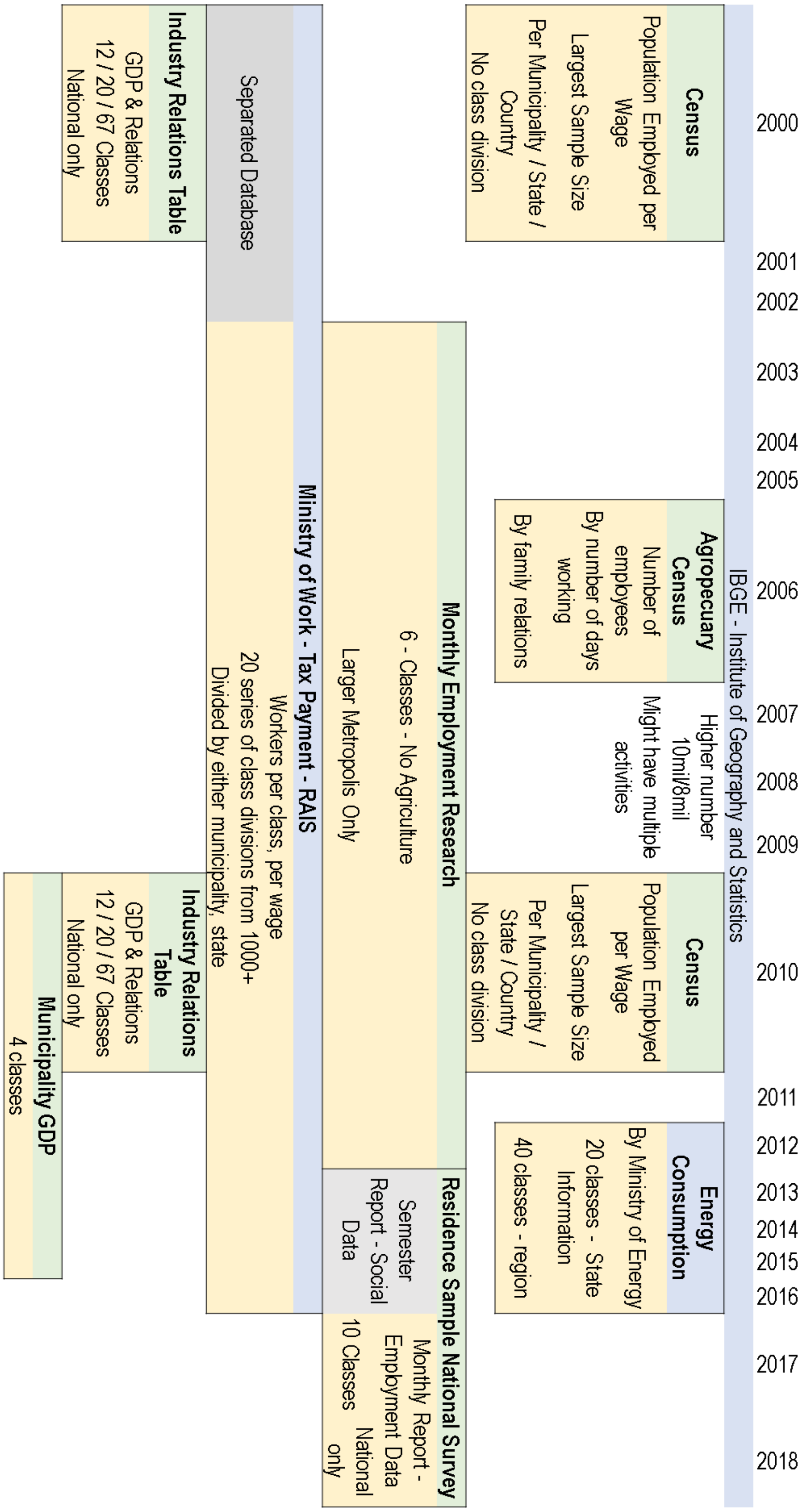


Figure 5.7 – Available data for supplement taxes information

The integration of categories between those different sources of data might cause difficulties in understanding the whole procedure, as the divisions adopted by each type of data do not match, therefore is not only a matter of reclassifying the categories but at times establishing new divisions or merging categories together. In this matter, for each stage of the approximation of estimated employees per sector one different grouping was made, as a rule, the chosen classification of the tax data, CNAE 2.0 – Groups, that was to be finally used in the production approximation was respected. For using the Municipality GDP (Brazilian Institute of Geography and Statistics, 2016) as an example, the value added per public health sector was grouped together with public education and public administration; however, the tax registries do not separate the employees of health and education between private and public. The Appendix A.6 summarizes the reclassification made between RAIS classification of employees, Supply and Demand Matrix classification of production sectors, Municipality GDP classification of value added and the PNAD classification of activities.

5.4 Assimilation of data

The value of income registered in the tax data is classified as a fraction or factor of minimum wage in 12 divisions that range from less than a half until more than 20 times the minimum wage, to use those values a simple mean of the range was calculated (from half to one became 0.75 and so on) and the average wage per CNAE2.0 category was multiplied by the calculated national distribution of employees.

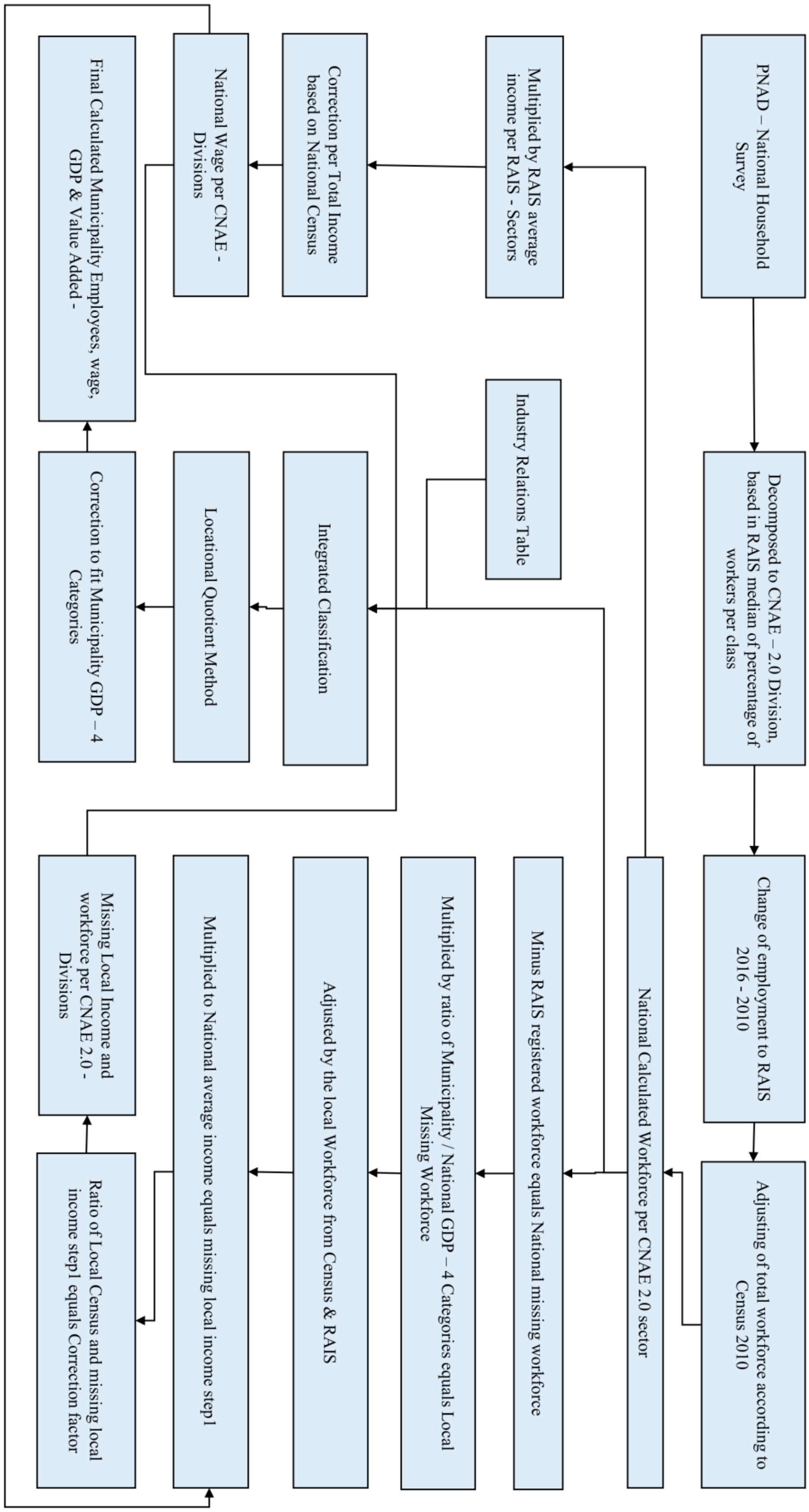


Figure 5.8 – Data Assimilation workflow

DESCRIPTION OF DATA ASSIMILATION PROCESS:

1. In the National House Sample Survey of 2017, the distribution of workers is presented divided in 10 economic activities.

2. a. The 10 classes from PNAD 2017 were matched with 86 classes from RAIS (Excluding the class 87 – International Organisms and Associations).

b. From the number of workers in each municipality, the percentage of workers in each category was calculated. The median percentage between all municipalities was used to estimate the total number of workers inside each of PNAD categories.

3. Using the change in employment registered in RAIS for each category for 2010 to 2016, the number of workers was firstly adjusted.

4. Using the Census data for number of people in economically active age that had income, the total number of employees was adjusted to match the number of employees in the Cenus.

5. The result is the National Estimated Workforce for each category in 87 categories (L_{NE}).

6. RAIS average calculated wage per category is a simple mean of the interval multiplied by the minimum wage which first approach to National Average Income

7. This income was adjusted based on total income registered in Census, for economically active people with income, by multiplying for a factor of 99,21%, so that both the estimation and the Census have an equal value for sum of total payroll.

8. This calculated value is the National average income per sector.

9. The difference between the L_{NE} and the measured workforce in RAIS taxes data is the National Missing Workforce (LNM).

10. The L_{NE} multiplied by the Municipality GDP of approached locality and divided by the sum of all municipalities GDP, for 3 categories (the reclassification is further detailed in in Appendix A.6) equals the Local Workforce Step1.

11. The local missing workforce is the difference between local workforce (step 1) and the local workforce registered in RAIS adjusted based on the Census and on the total registered workforce, resulting in local workforce (step2).

12.The Local Workforce Step 2 is multiplied to the National Average income for each sector resulting in a total local payroll (step1).

13. The ratio between total local payroll (step1) and the average income registered in the census equals a correction factor.

14. The correction factor times the National Average income is the Calculated Local Income.

15. The number of employees and calculated income are reclassified in the Integrated Classification to match working categories to the production categories in the National Industry Relations Table.

16. The Revenue and Value Added from National Industry Relations table are reclassified to the Integrated Classification.

17. The locational Quotient method is applied to calculate local revenue and value added.

18. The Local Revenue and Value Added are corrected to match the Municipality GDP.

19. The final result is the calculated Workforce, Wages, Revenue and Value added for each category of the Integrated Classification.

For the validation of the proposed approach on data assimilation, the calculation of the Locational Quotient and the estimation of the local economy for the Rio Grande do Sul State was made and the results were compared to the values obtained by Brene (2013).

As the validation presented acceptable values, the same method was applied for the taxes and Census data for the municipality of Irai, the formulas obtained from the regression of the values corrected with the inflation values of the GDP deflator were used to calculate a maximum damage discretized for each one of the 53 categories from the Modified CNAE 2.0 classification. The complete results of the calculation are synthetized in Appendix A.7..

To verify the possibility of estimation of construction footprint area from the population Grid from the *Grade Estatistica*(IBGE, 2016) a careful delineation of each building in the municipality central region and immediate adjacent areas was made through the usage of satellite imagery (GoogleEarth, 2018), as exemplified in Figure 5.9, a total of 3000 buildings were mapped by identification of rooftops, the results of comparison of the two products revealed a correlation of 0.64 between number of inhabitants in the population Grid and measured constructed area and a correlation of 0.75 between number of households registered in the population Grid and the measured constructed area.

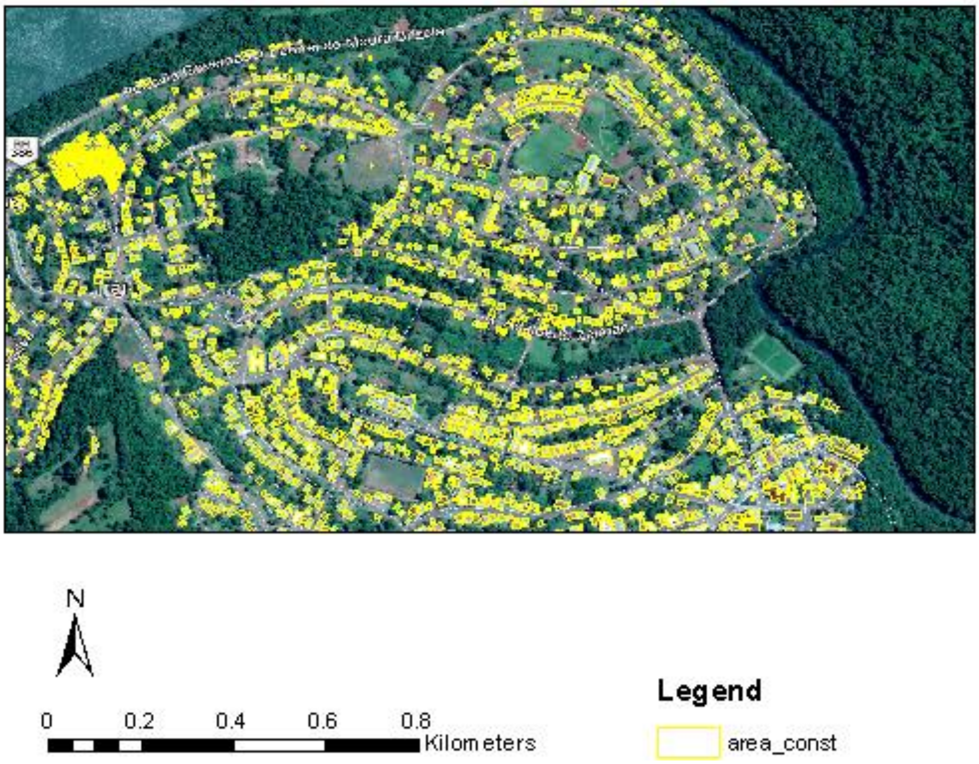


Figure 5.9 - Satellite imagery (GoogleEarth) and overlay of building footprint delimited in ArcGIS.

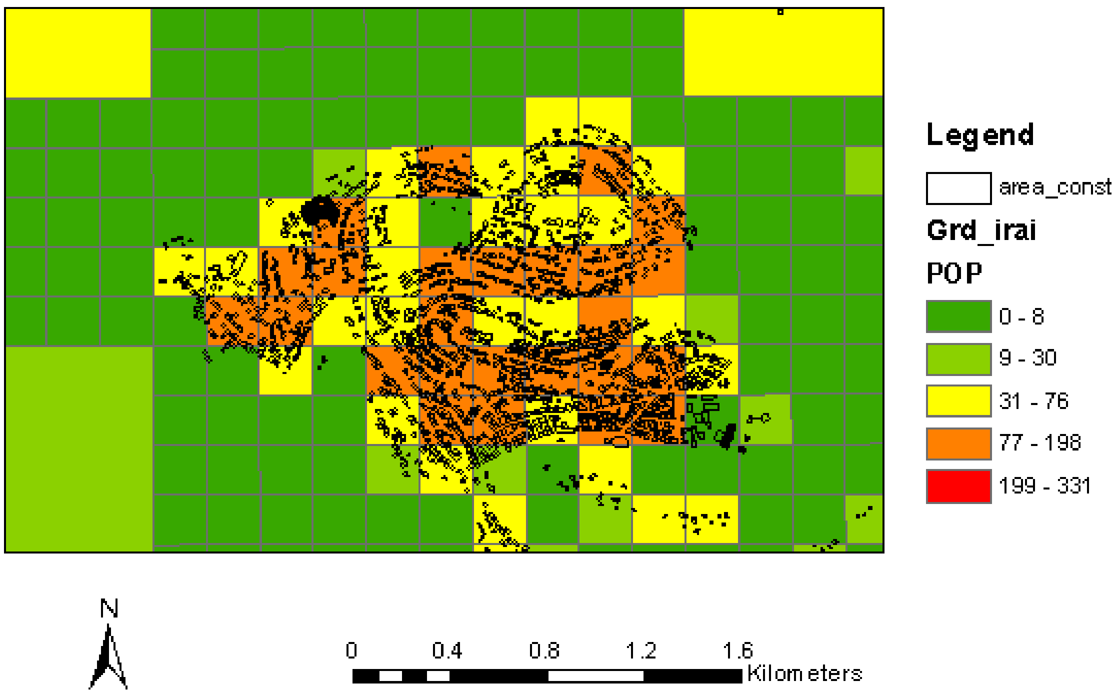


Figure 5.10 - Overlay of the building footprint and the Population GRID (IBGE, 2016)

The usage of this data would be interesting for both regional analysis and for inter-comparison between different local studies, due to its availability for the whole country, however, further consideration should be done about an upper limit of constructed area, as densely populated areas are expected to have more buildings with 2 or more floors, which would lead to an overestimation. Considering the upper floors on risk analysis is important both for damage assessment as for life threaten assessment, as people can temporarily evacuate for upper floors and await for rescue during floods.

Therefore, the *shapefile* containing the absolute values was converted into a raster file containing relative percentage of buildings, using the value from number of households from the original file as the indicator of percentage of constructed area.

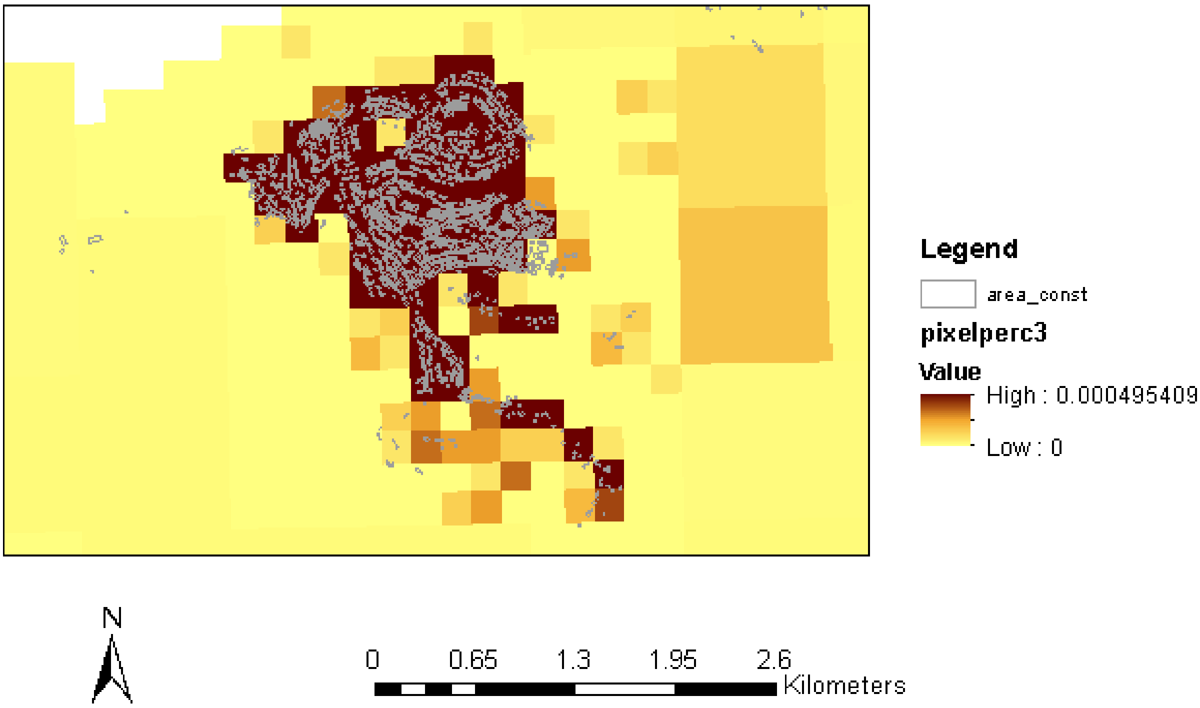


Figure 5.11 – Raster file of relative distribution of buildings in a 30m x 30m grid cell.

For calculation of percentage of agriculture per area, the Global Land Cover by National Mapping Organizations (Tateishi et al, 2011, 2014) was reclassified and all categories that include either livestock or agriculture were grouped.

5.5 Calculation of Damage

For the calculation of maximum residential damage, the average size of household per social class and maximum damage per meter square calculated by Machado (2005) were used; the number of household per social class was obtained from IBGE, and the product of total households area was multiplied for the maximum damage, obtaining the maximum total damage of all households in the municipality.

To calculate the total damage, the flood depths were multiplied by the equations derived from the normalized depth damage curves proposed by Huizinga et al (2017), (Table 5.3) a threshold was set at 0.2m for zero damage in all the functions. By Multiplying those raster files a total damage raster file is produced in which the sum of all pixels, extracted with the Zonal Statistics as Table in ArcGIS represent the total damage of each sector as a percentage of calculated maximum damage.

Table 5.3 Normalized flood depth damage functions

	Flood depth – Normalized Damage Function
Residential	**Dmg = 0.272ln(x) + 0.7145**
Industry & Services	**Dmg = 0.3072ln(x) + 0.8386**
Commerce	**Dmg = 0.3012ln(x) + 0.8063**
Agriculture	**Dmg = 0.2581ln(x) + 0.489**

Where *Dmg* is normalized damage and *h* is water height (lower threshold of 0.2m)

Finally, the multiplication of the percentage of building footprint raster by the normalized damage raster results in a raster in which each pixel represents a percentage of damage in the relation of the maximum total damage for the municipality. By using zonal statistics tool in ArcGIS, the total damage as a fraction of maximum damage for the municipality is obtained for each of the urban sectors: residential, commercial and industry & services; the same for agricultural normalized damage raster and the normalized land use map.

Table 5.4 Damage percentage per return period

Return Period (Years)	Cat.	5	10	25	50	100	1000
Damage Factor - Percentage of Maximum Damage	R	11%	17%	23%	27%	30 %	45%
	A	6%	7%	8%	9 %	10%	14%
	I&S	11%	17%	23 %	27%	31%	46%
	C	11%	17%	23%	27%	31%	46%

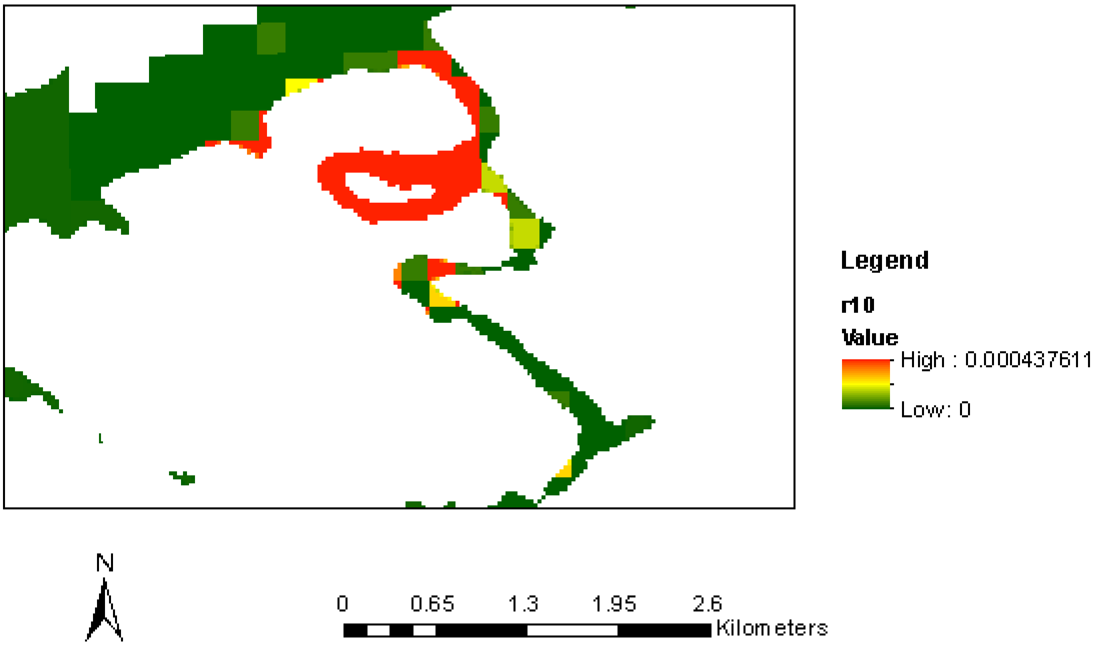


Figure 5.12 – Total damage raster for residential damage and return period of 10 years.

6. RESULTS AND DISCUSSION

6.1 Hazard Map and Damage Calculation

The results of the hydrological simulations are previously described are displayed as the hazard maps for each of the return periods (Appendix A.3); the relative affected area in the urban center of the municipality is much larger than the overall political boundary, the municipality developed in a flood prone area even when safer land was available for development. This is result of lack of previous studies that would enable technical and scientifically decisions on urban planning, and of insufficient conscience or legal regulation.

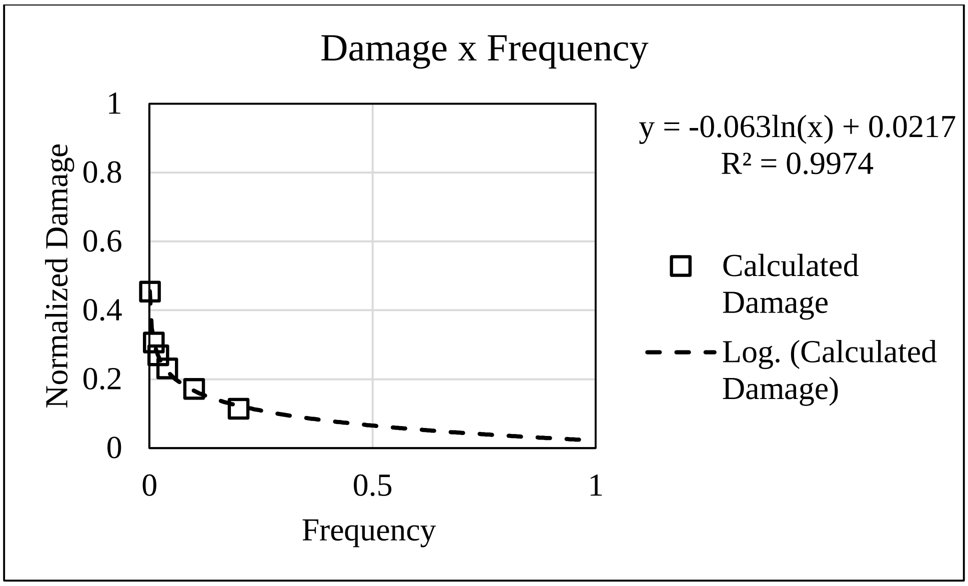


Figure 6.1 Average Normalized Damage per Frequency

The discretization of the disaster damage data per economy sector is also the target C-3 of the Sendai Framework for Risk Reduction (UNISDR, 2015); for developing countries, the database of past damage records is not always available or well detailed, Yokomatsu et al (2013) emphasized the difficulty in reaching high levels of details in micro scale as a limitation in studies of economic assessment of disasters.

For the effect of calculating the damage, the economy sectors of *Domestic Services* and *International Organisms and Institutions* were not considered, this is because from the theoretical standpoint, those sectors, even though generate income, cannot be explained from the Cobb Douglas production function interpretation. The *Domestic Services* for example is mainly represented by housekeeping service, when a professional works and generates income directly in a family household, therefore, is hard to try to fit a concept of capital in such activity, that might be interpreted as completely moved by the share of labor. The *International Organisms and Institutions* on the other hand, receive taxes or funding from external communities, therefore also it would not be reasonable to fit a value of capital for such. While the Vincelette (2010) discusses fitting of official data into understandable parameters through the conventional production functions, some caution should be taken into consideration of both human development and nature of each activity in the distribution of share of capital and share of labor, the same discussion can be done to public services and for security services, that can be seen as an intermediate between purely labor shared activities and conventional Cobb Douglas production type activities.

Table 6.1 - Summary of calculated damage (A – Agriculture, R – Residential, I&S – Industry and Services, C – Commerce (values in 2010 – R$).

Return Period (years)						
	5	10	25	50	100	1000
Maximum Damage Calculated from National GDP:						
R	43,535,619	66,515,649	90,284,334	105,499,401	120,198,203	178,331,155
I&S	24,703,215	37,037,225	49,922,831	58,118,632	66,184,708	98,053,498
C	20,782,037	31,294,370	42,239,167	49,198,505	56,023,198	83,004,177
Maximum Damage Calculated from National GDP – 60% Undamageable:						
R	31,926,120	48,778,143	66,208,511	77,366,227	88,145,349	130,776,180
I&S	19,762,572	29,629,780	39,938,265	46,494,905	52,947,766	78,442,798
C	17,456,911	26,287,271	35,480,900	41,326,744	47,059,486	69,723,509
Maximum Damage Calculated from Municipality GDP:						
R	32,553,974	49,737,405	67,510,556	78,887,697	89,878,799	133,348,001
I&S	18,866,612	28,286,478	38,127,614	44,387,002	50,547,314	74,886,498
C	16,260,028	24,484,958	33,048,253	38,493,293	43,832,986	64,943,114
From Municipality GDP – 60% Undamageable:						
R	23,872,914	36,474,097	49,507,741	57,850,978	65,911,119	97,788,534
I&S	15,093,289	22,629,182	30,502,091	35,509,601	40,437,851	59,909,198
C	13,658,423	20,567,365	27,760,533	32,334,366	36,819,709	54,552,216
Maximum Residential Damage Calculated from Social class adapted from (MACHADO 2004) Maximum Damage of economy sectors from Value Added per Employee and Production per Employee:						
	5	10	25	50	100	1,000
R	3,927,631	6,207,428	8,425,586	9,836,998	11,218,417	16,627,331
A	187,108	226,001	269,739	305,299	339,520	460,552
I&S	24,378	38,111	51,370	59,733	68,112	100,780
C	1,055,552	1,652,670	2,230,667	2,595,459	2,958,968	4,378,861
With Correction Factor (4,05 times)						
C, I &S	5,131,504	7,762,967	10,334,690	11,989,988	13,634,729	20,007,781

Huizinga (2017) already discussed the overestimation of the damages for developing countries therefore, for additional validation, the process of estimating maximum damage was repeated for the municipality of Itajuba in Minas Gerais State, the results were compared to the maximum possible damage for the commerce sector, calculated from the total are and flood depth damage curves prepared by Cortes (2009); the results were 4.05 times larger than the method here proposed; suggesting the method still needs adjustment. This might have been caused by distortions in the calculated econometric parameter or another possibility is that this difference was caused by an incorrect value in the axis of value added per employee and maximum revenue per employee, in this case, the curves in Figures 5.2 to 5.5 should be remade with recent data for checking. Currency in Brazil passed through several changes since the data was gathered, including periods of extreme inflation rates and this might have caused unrealistic values, the relation between an economy sector and the maximum damage it can suffer even though is still expected to be confirmed.

Schadeck (2016) provides a summary of official reported damage from natural disasters from 1995 to 2014 in map format, the results for Irai range in between R$16 million to R$36 million. In comparison, the calculated damage for a 25 year return period (Table 6.1) ranged from R$ 100 million to R$ 200 million when applying the calculation method based on GDP (Huizinga, 2017) and reached R$ 10 million and R$ 18 million in the method proposed and after application of correction factor, respectively.

In the event of June 2014, the rainfall reached an accumulated of 163mm, which is very near the 50 year return period event. The damage record was obtained from Mikosz (2018) who made a compilation of official reports damage from the Integrated System of Disaster Information (S2ID) and from the information on demand from CEPED (2018) both presented the same values for direct damage and the record from CEPED also pointed an additional R$ 8 million for indirect losses. From a comparison with those values, we observe that the residential damage is still overestimated; which may be caused by social segregation, causing poorer people to live in flood prone areas while wealthier people live in safer locations. Also, damages do not include agriculture, commercial and industrial sectors, this might be caused by either inherent bias of data acquisition or by the spatial distribution of those sectors, that might also be placed in safer areas.

Table 6.2 – Official reported damages (Mikosz, 2018)

Damaged Houses	424
Destroyed Houses	36
Residential damage	2,589,360
Damages in health sector	60,000
Damage in education sector	72,000
Damage in other public services	2,358,000
Damage in community structures	230,000
damage in infrastructure	1,980,000
Damage in agriculture, industry & commerce	Not registered
Total damage registered	7,289,360

The proposed method if improved and further validated in others studies it might possibly be used by developing nations to discretize this damage and also to project discretized damage in the future and consider the vulnerability and strategic development of each sector. It can be expected that, as same as in Brazil, the economy sector has a greater amount of interest from the authorities and society in relation to risk management, therefore it is wise to take advantage of the data already produced by these sectors.

To illustrate the effect that this relation between flood maximum damage and econometric parameters in the economy growth of each sector, a simple growth simulation was prepared (Figure 6.2) and in sequence, a Monte Carlo simulation was performed to introduce the effect of flood damage (Figure 6.3).

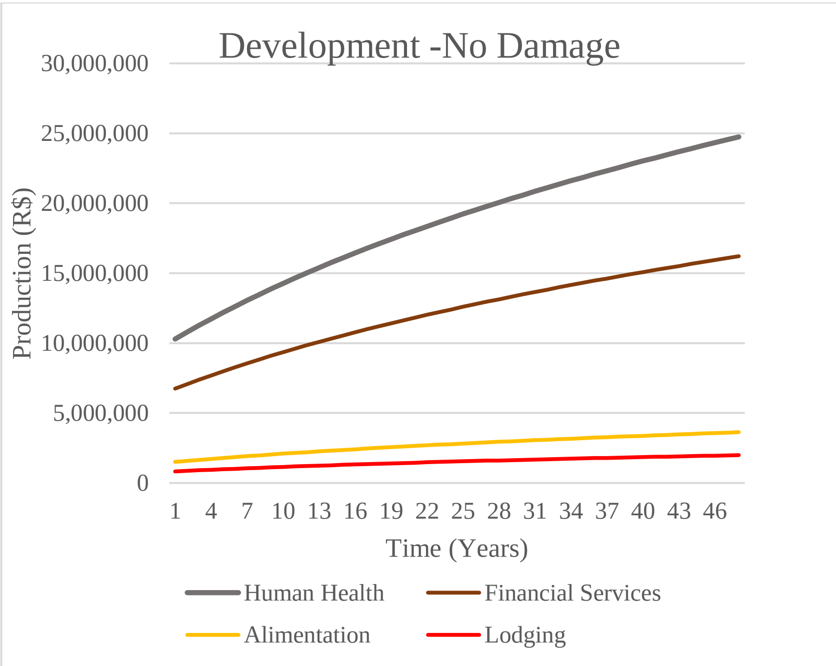


Figure 6.2 - Economic growth simulation

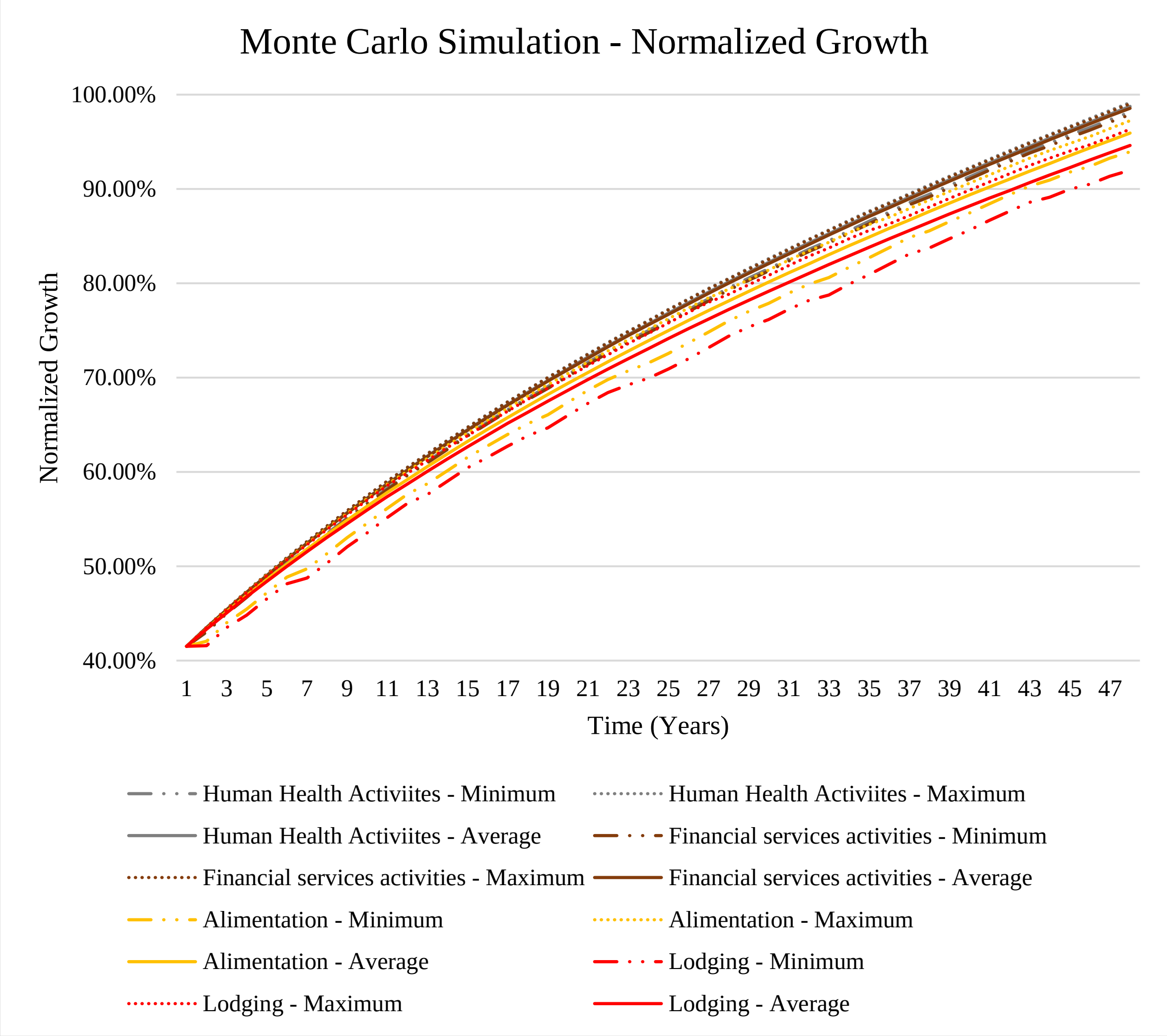


Figure 6.3 – Normalized Monte Carlo Simulation with growth considering flood damage

The consequences of the control of maximum damage by econometric parameters are illustrated in Figure 6.3, which is the result of a Monte Carlo type simulation prepared in Microsoft Excel using the Equation 6.1. The simulation considered three thousand randomized scenarios for a 50-year series. It is observed that activities that rely more on physical capital (lodging), are more impacted than activities that rely more on human capital (financial services).

$$\boldsymbol{Y} = [(\boldsymbol{K} * \boldsymbol{\delta}) + \boldsymbol{I} - \boldsymbol{D}]^{\alpha} * (\boldsymbol{L} *)^{\beta}$$

Equation 6.1 – Solow growth model in Monte Carlo type simulation for incorporating the flood damage, where Y: Production; K: Capital; δ: Deprecation; I: Investment; D: Damage, L: Labor, α: Capital share of output; β: Labor share of Output.

Kraay (2005) discussed several indicators between international aid, economic growth and reduction of poverty and inequality, proposing a measure of sensitivity of poverty to growth, this effect could also be related increased vulnerability of less developed economies to disasters.

6.2. About Possible Countermeasures

The flood events in the study areas have the characteristic of not so widespread area and relatively deep waters, due to the morphology of the basin. The 50-year return period for an example can reach up to 17m from the normal river height. This nature makes it difficult to consider certain structures, such as levees or other structures within the municipality urban area.

In such cases, flood control dams might achieve the best possible results in terms of flood reduction. This type of structure, or a combination of flood control dams can affect the whole basin, therefore, an interesting option in this case would be to make a complete damage assessment for the basin and consider the cost and benefit for different combinations of this approach.

7. CONCLUSION

The methodology was successfully applied for the study area, the results for damage estimation proved interesting and are more near to a match than the other tested approaches and continuous improve and testing of the methodology presented is recommended.

Both the hydrological models could still be improved with the same choice of platform for simulation by enhancing the pre-processing of data, by improving spatial resolution for both models until computational capacity is further pushed and by using other stations for calibration.

The present method for flood risk sectoring used by the Geological Survey of Brazil could be improved with usage of similar study methods, considering extreme event frequency analysis and damage functions for damage loss projections. Even though in terms of spatial precision, the areas mapped in fieldwork presented a good precision when compared to the satellite imagery used for calibration. Which suggests that this product could be used for calibration of models and eventually for supporting interpretations due to imperfections of the currently available DEMs that can be used for the country.

From the relation described in Figures 5.2 to 5.5 a first analysis can suggest that if inside a community if there is no selective spatial segregation of activities by efficiency or income versus flood hazard, the overall level of development of a community will determine the proportion between maximum damage and the total production output. This implies that less developed communities will be more harshly impacted by the flood events, and even inside the communities, the flood are expected to cause proportionally more damage to the less developed segments. This spatial segregation is intuitively expected to happen both for residential and economic distribution, as people and sectors with more resources can afford to occupy areas with lower risk, this means that acting in flood prevention is not only an approach to improve overall development of an economy, but also a way to reduce inequality.

In developing economies, historical flood damage data is not always available to prepare adequate flood depth versus damage curves; additionally, studying the future damage by the traditional approach requires a good knowledge of the locality, such as number of establishments, area, value of building and contents and spatial distribution of them.Optimizing funds allocation for studies in risk evaluation is a priority of all authorities, therefore, using all the data that is already available before planning more data acquisition is an interesting option to consider.

The method proposed in this study, if further validated in additional studies, can provide a framework for providing a flood damage cost analysis that can be applied in the whole country, by using data from several institutions. The Brazilian governmental institutions themselves have displayed a great effort to continuously improve the data they provide, such as adapting their classification methods based in international standards, improving sampling size and distribution and providing quicker and easier access to the data, the authorities on risk management and the decision making authorities should always be willing and be prepared to adapt their methods of analysis in order to assimilate more data as the quality can be expected to continue to be improved.

This approach can generate ample data for feasibility studies in basin wide interventions; dam operations is an example, even those designed for energy generation can preserve a share of the reservoirs for flood control, which leads to preventing damage downstream but leads to reduced energy availability, water supply security should also be taken in regard carefully, but as for losses in the energy sector those can be compared with the damage prevented and used as a decision criteria by the proper authorities. In case of the Uruguai River basin, there is a large number of dams and an even larger number of affected municipalities, including Argentinian and Uruguayan cities, which suffer damage from the extreme events, the complete damage assessment and hydraulic-hydrological simulations of the provided benefits are the a feasible alternative for comparison of the costs of such operations.

The approach used in the present study, if coupled with economic growth projections might provide a measureable change in growth itself by implementation of flood control measures rather than simply calculate the instant damage and also by discretizing the damage in each sector the changes in inequality can be projected within the community itself, as well as in between communities.

APPENDIX

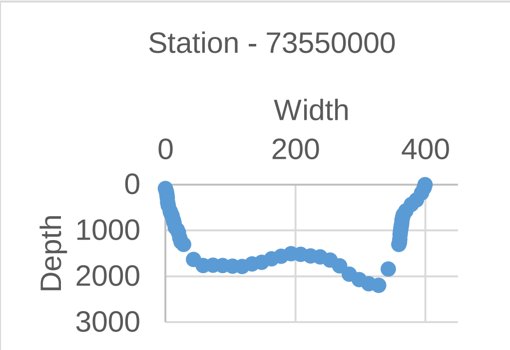
A.1. Relation of rain gauge stations considered in this study

0265 0017	SÃO JOÃO DE CIMA	0275 1011	IRANI	0284 9023	DESPRAIADO
0265 0019	LEBON REGIS	0275 1012	CAPINZAL	0284 9035	SILVEIRA
0265 0032	SANTA CECÍLIA	0275 1015	BARRACÃO	0285 0001	BOM JESUS
0265 1002	CAÇADOR	0275 1016	VIDEIRA	0285 0003	COXILHA GRANDE
0265 1022	SANTO AGOSTINHO	0275 1017	CLEMENTE ARGOLO	0285 0004	COXILHA RICA
0265 1033	FAZENDA SANTO AGOSTINHO	0275 1018	MARCELINO RAMOS	0285 0006	INVERNADA VELHA
0265 1036	QUILOMETRO 30	0275 1020	JOAÇABA	0285 0007	PASSO DA GARRAFA
0265 1040	PONTE SERRADA	0275 1021	JABORÁ	0285 0008	PASSO SOCORRO
0265 1044	CALMON	0275 1025	PINHAL DA SERRA	0285 0009	PASSO TAINHAS
0265 2000	ABELARDO LUZ	0275 2001	RIO INHUPACÁ	0285 0010	USINA TOUROS
0265 2001	BONITO	0275 2002	BARRAGEM RIO PASSO FUNDO	0285 0011	VACARIA
0265 2002	MARATA	0275 2003	USINA CHAPECÓ (FLCSA)	0285 0012	BOM JESUS (APARADOS DA SERRA)
0265 2004	PASSO NOVA ERECHIM	0275 2004	CHAPECÓ - AGROPECUÁRIA	0285 0015	ESCURINHO
0265 2005	PORTO ELVINO	0275 2005	CONCORDIA	0285 0016	CAZUZA FERREIRA
0265 2006	XANXERE	0275 2007	ERECHIM	0285 0020	MONTE ALEGRE DOS CAMPOS
0265 2021	JARDINÓPOLIS	0275 2008	JOSÉ BONIFÁCIO	0285 0024	PASSO DO HONORATO
0265 2031	SÃO LOURENÇO DO OESTE	0275 2009	MONTE ALEGRE	0285 0025	SOCORRO
0265 2034	PORTO FAE NOVO	0275 2010	NONOAI	0285 0026	SANTANA
0265 2045	PRAINHA DO OURO VERDE	0275 2011	QUATRO IRMÃOS	0285 0027	PELOTINHAS
0265 3001	CAMPO ERE - EMPASC	0275 2012	RONDA ALTA	0285 0028	VACAS GORDAS
0265 3003	MODELO	0275 2013	SARANDI	0285 1007	ENCRUZILHADA II
0265 3004	PONTE DO SARGENTO	0275 2014	CHARRUA	0285 1008	ITUIM (ENTRE RIOS)
0265 3006	SÃO MIGUEL D'OESTE I	0275 2016	CHAPECÓ	0285 1010	FAZENDA ROSEIRA

0265 3007	SAUDADES	0275 2017	ITATIBA DO SUL	0285 1013	LAGOA VERMELHA I
0265 3011	SÃO MIGUEL D'OESTE	0275 2021	GAURAMA	0285 1014	LAGOA VERMELHA
0265 3013	PALMA SOLA	0275 3001	BARRAGEM JOÃO AMADO	0285 1020	PASSO DAS PEDRAS
0265 3022	FAXINAL DO CAMPO ERE	0275 3002	FREDERICO WESTPHALEN	0285 1023	PONTE SANTA RITA
0265 3023	RINCÃO DO CAPETINGA	0275 3003	IRAÍ	0285 1030	USINA DO POSTO
0265 3029	PARAÍSO	0275 3004	LINHA CESCON	0285 1032	USINA SALTINHO
0265 3030	RAIGÃO ALTO	0275 3005	PALMEIRA DAS MISSÕES	0285 1043	ESMERALDA
0274 9009	RIO BONITO	0275 3006	PALMITOS	0285 1050	CAPÃO DO CEDRO
0274 9031	VILA CANOAS	0275 3007	SANTO AUGUSTO	0285 1051	MUITOS CAPÕES
0274 9032	SANTA CLARA	0275 3008	TENENTE PORTELA	0285 2001	AMETISTA
0274 9035	BOCAINA DO SUL	0275 3009	TRÊS PASSOS	0285 2007	COLÔNIA XADREZ
0275 0001	CAMPO BELO DO SUL	0275 3010	USINA GUARITA	0285 2010	ENGENHEIRO ENGLERT
0275 0002	CURITIBANOS	0275 3013	IPORÃ	0285 2020	PASSO FUNDO
0275 0003	ENCRUZILHADA II	0275 3014	LIBERATO SALZANO	0285 2022	PONTÃO
0275 0004	FRAIBURGO I	0275 3015	PALMEIRA DAS MISSÕES	0285 2027	TAPEJARA
0275 0005	LAGES	0275 3016	MIRAGUAI	0285 2046	TAPEJARA
0275 0007	PAINEL	0275 3019	IRAÍ	0285 2049	USINA ANONI
0275 0008	PASSO CARU	0275 3024	BARRA DO GUARITA	0285 2052	CAMPO DO MEIO
0275 0009	PASSO MAROMBAS	0275 3025	CAMPO NOVO	0285 3026	CHAPADA
0275 0010	PONTE ALTA DO NORTE	0275 3026	PLANALTO	0285 4001	BOA VISTA
0275 0011	PONTE ALTA DO SUL	0275 4002	CRICIUMAL	0285 4003	GIRUA
0275 0012	PONTE DO RIO ANTINHAS	0275 4003	HORIZONTINA	0285 4020	CGH CARAGUATÁ - JUSANTE
0275 0013	PONTE DO RIO CORRENTE	0275 4004	USINA SANTA ROSA	0295 0003	AZULEGA
0275 0016	FRAIBURGO	0275 4005	SANTA ROSA	0295 0007	CAMBARÁDO SUL
0275 0020	SÃO JOSÉ DO CERRITO	0275 4006	SANTO CRISTO	0295 0008	CAMISAS
0275 0021	CABECEIRA RIBEIRÃO CAETANO	0275 4007	TRÊS DE MAIO	0295 0035	TAINHAS

0275 0022	PONTE ALTA DO NORTE - CIFSUL	0275 4008	TUPARENDI	0295 0054	CAMBARÁDO SUL
0275 1001	ANITA GARIBALDI	0275 4009	TUCUNDUVA	0295 0063	VILA TAINHAS
0275 1002	CAMPOS NOVOS	0275 4010	ESQUINA ARAUJO		
0275 1003	CAPINZAL (RVPSC)	0275 4013	CAMPINA DAS MISSÕES		
0275 1004	JOAÇABA	0275 4014	SÃO MARTINHO		
0275 1005	MARCELINO RAMOS	0275 4015	PORTO MAUÁ		
0275 1006	PAIM FILHO	0275 5001	PORTO LUCENA		
0275 1007	SANANDUVA	0284 9003	SÃO JOAQUIM		
0275 1008	USINA FORQUILHA	0284 9009	BOM JARDIM DA SERRA		
0275 1009	VIDEIRA (RVPSC)	0284 9014	SÃO JOAQUIM		
0275 1010	URUGUAI (RVPSC)	0284 9021	URUBICI		

A.2. River Cross sections considered in this study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400
Depth
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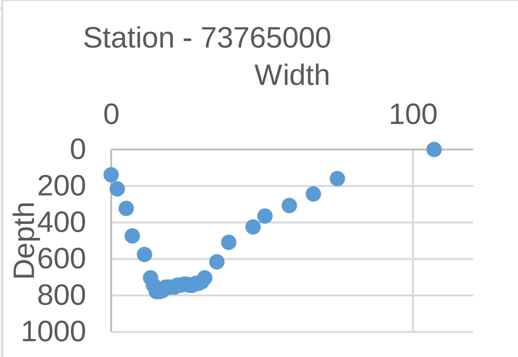
1000
2000
3000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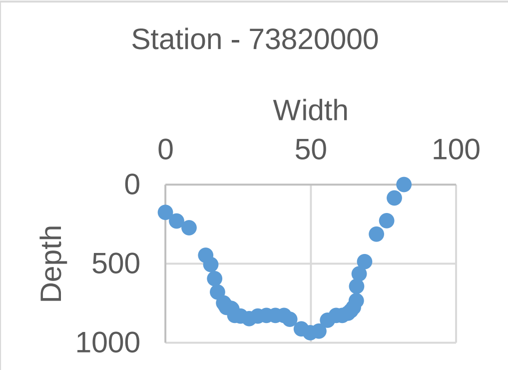
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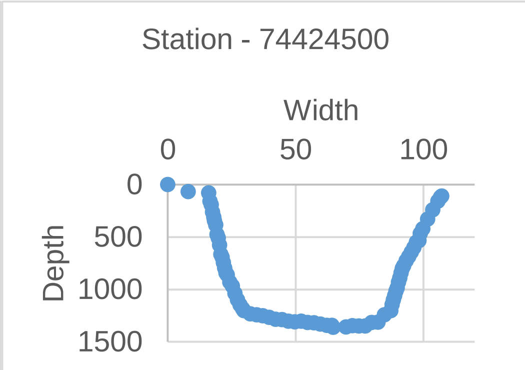
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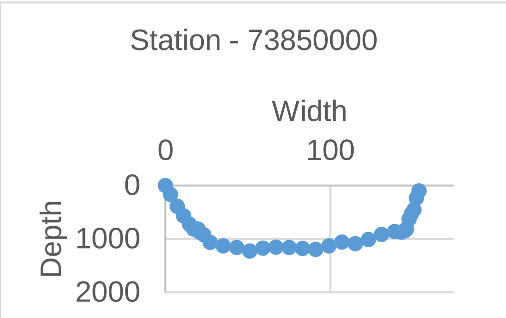
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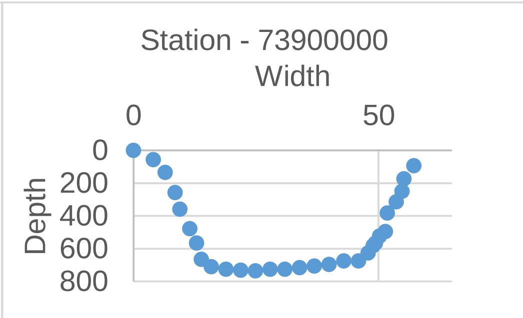
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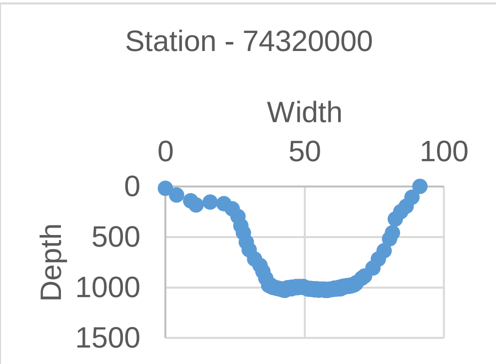
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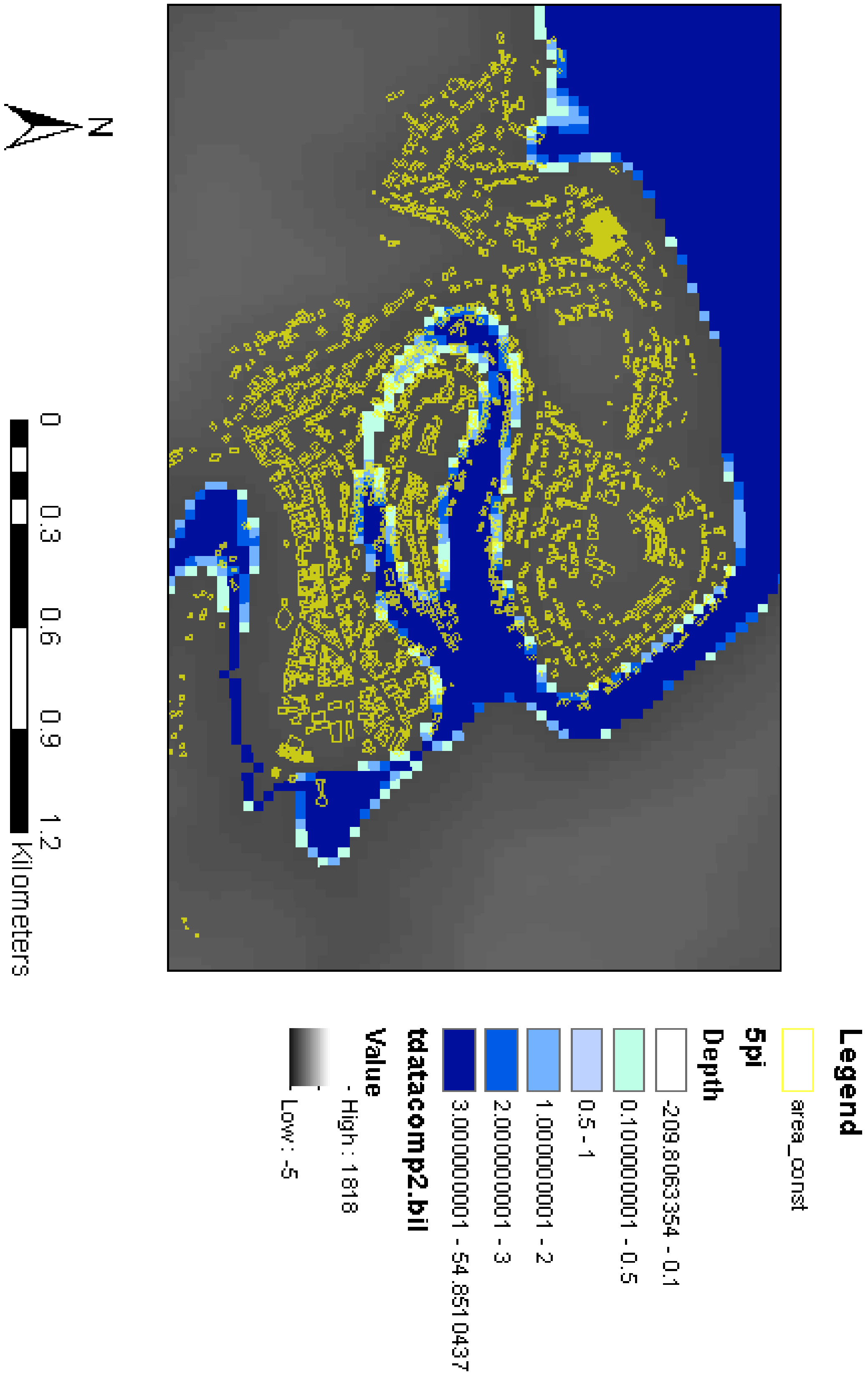
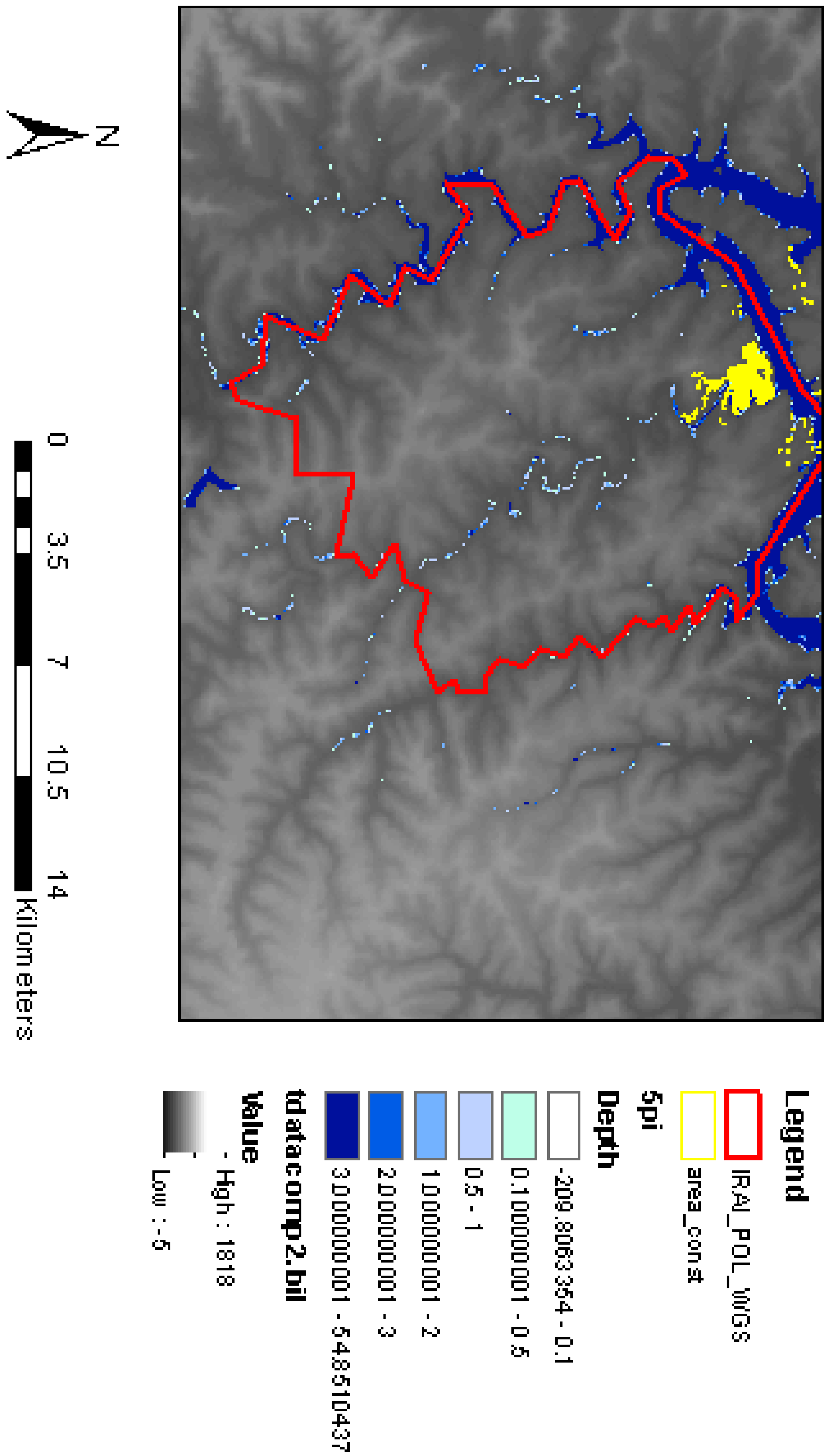
1500

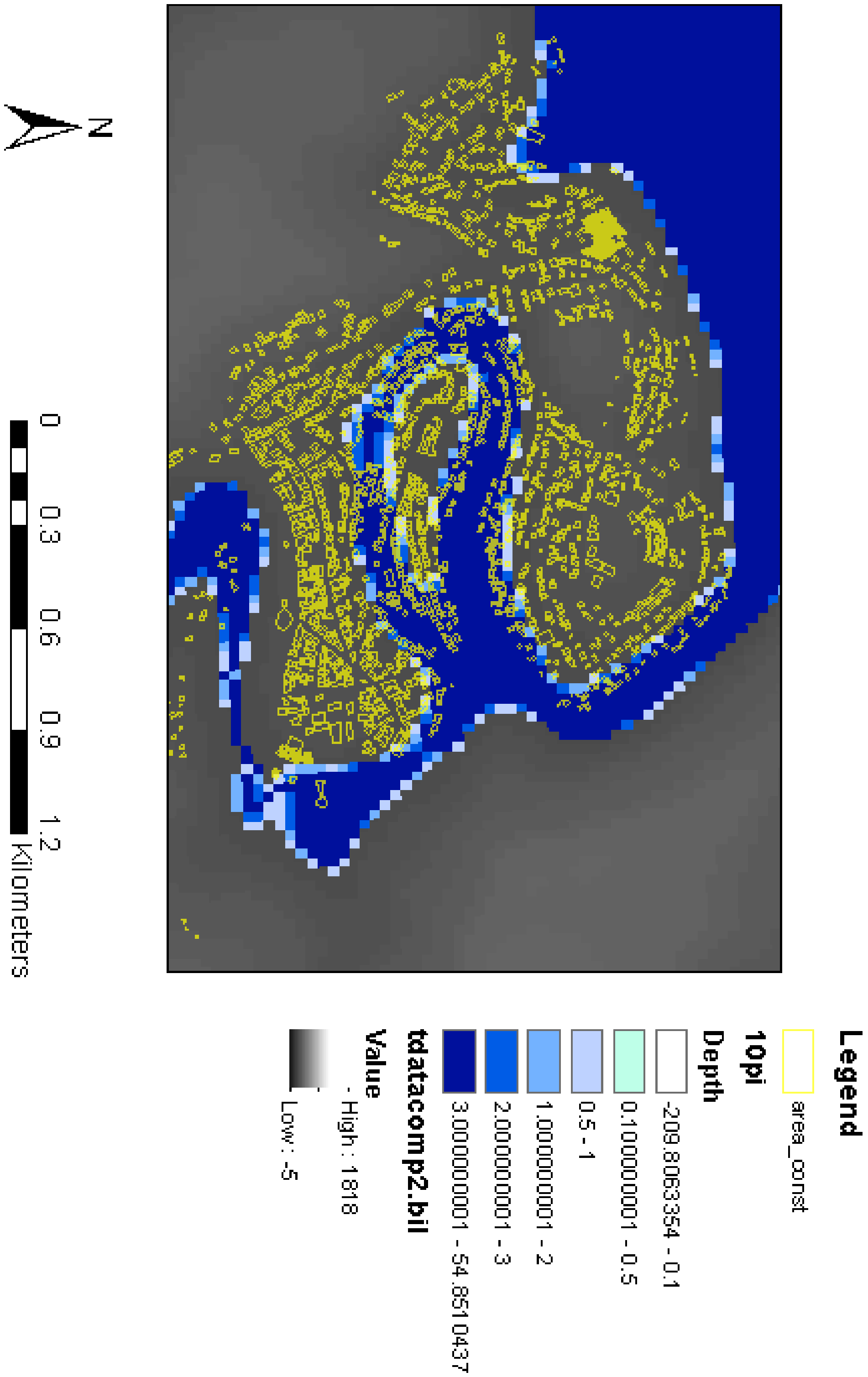
A.3. Floods affected areas per return period



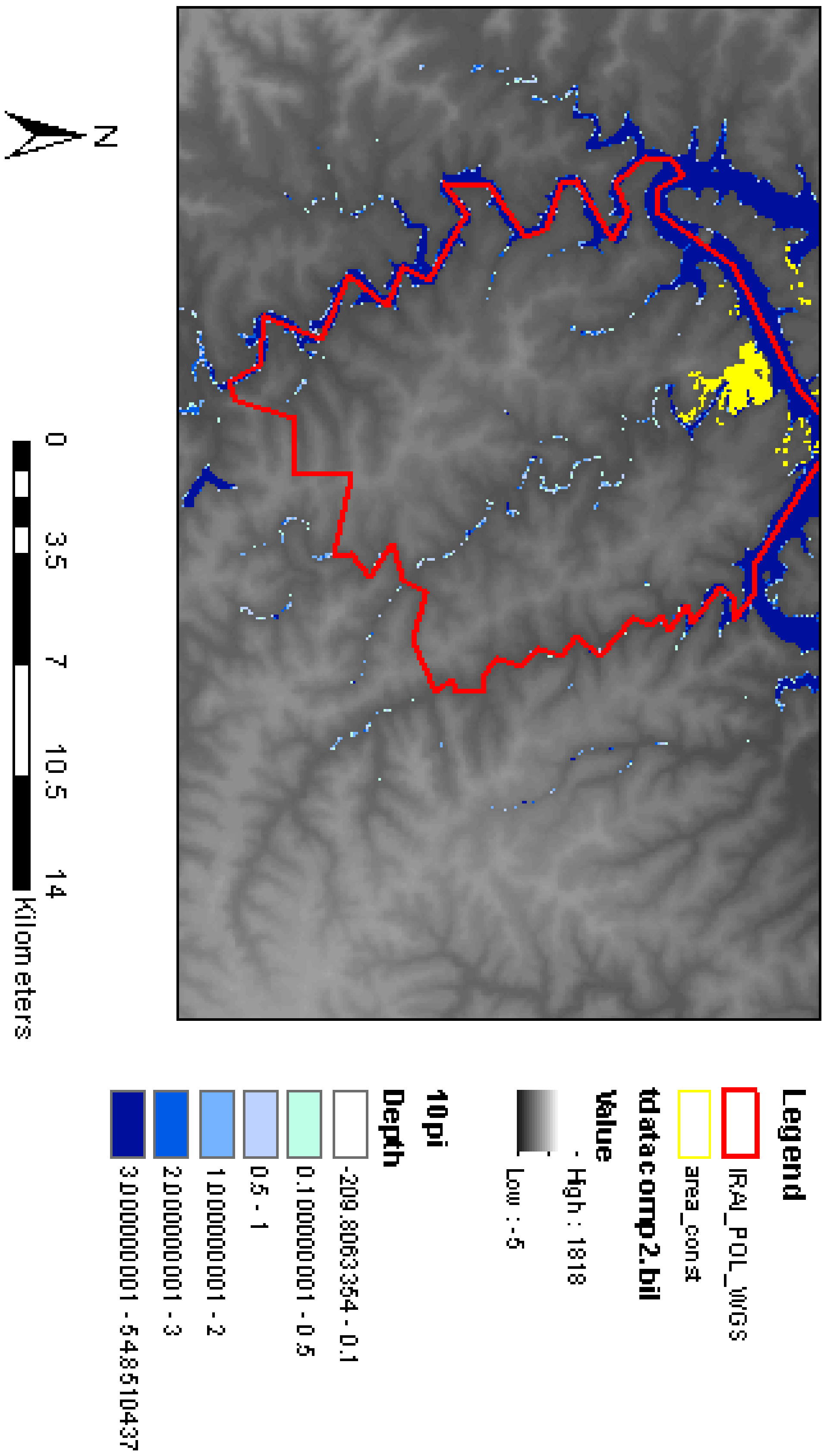
Affected area for 5 year return period flood – view on urban center



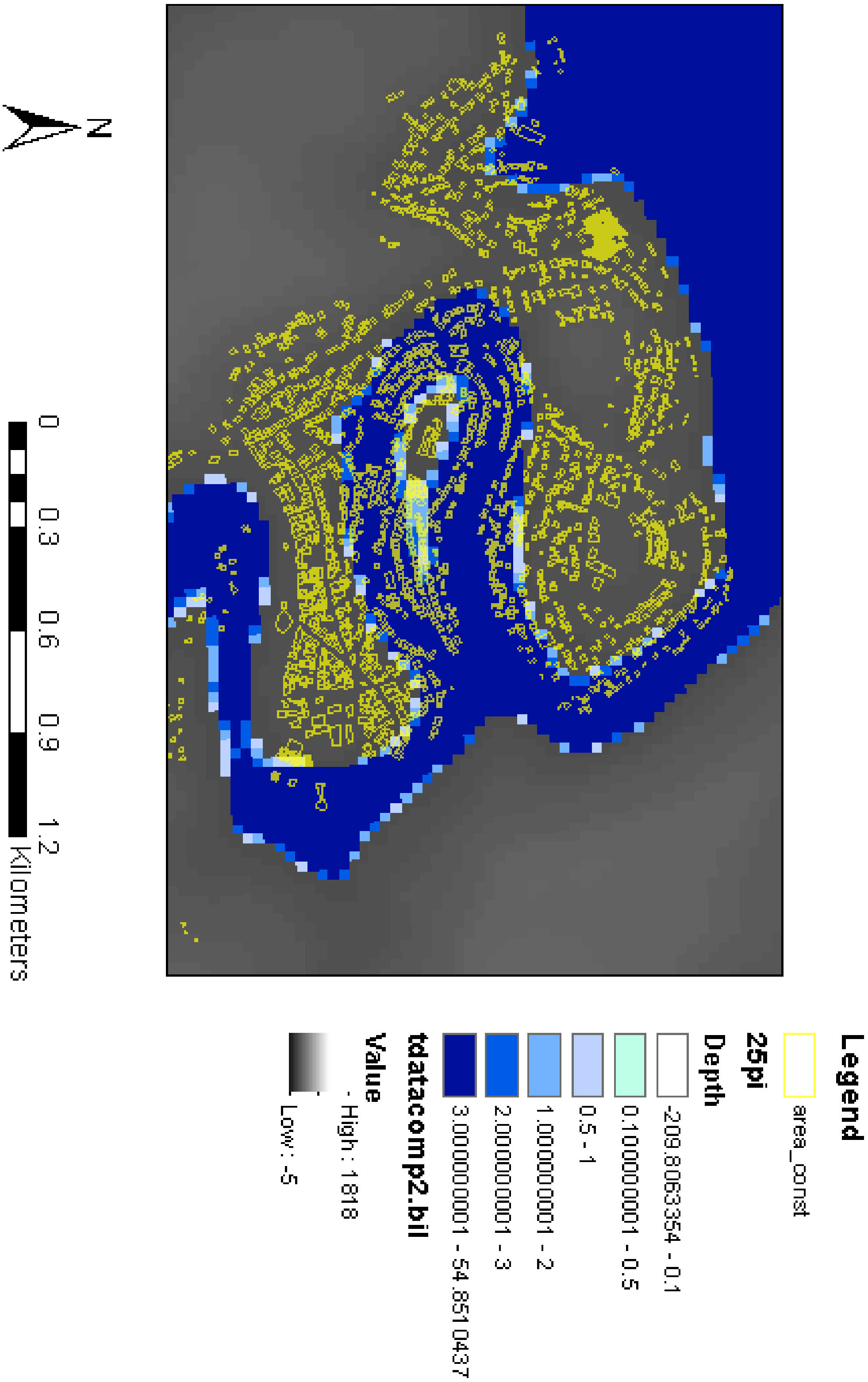
Affected area for 5 year return period flood – view on whole municipality



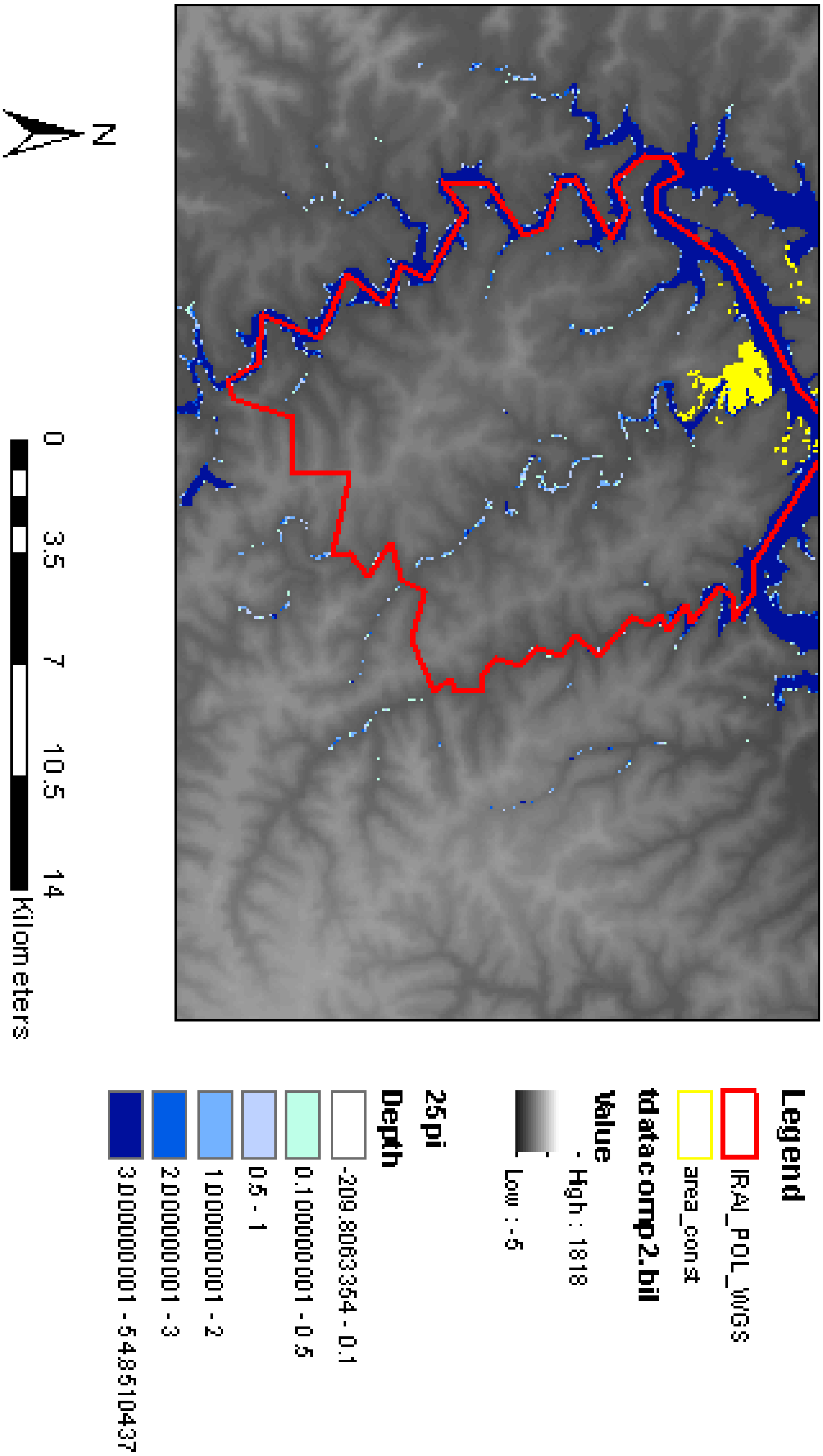
Affected area for 10 year return period flood – view on urban center



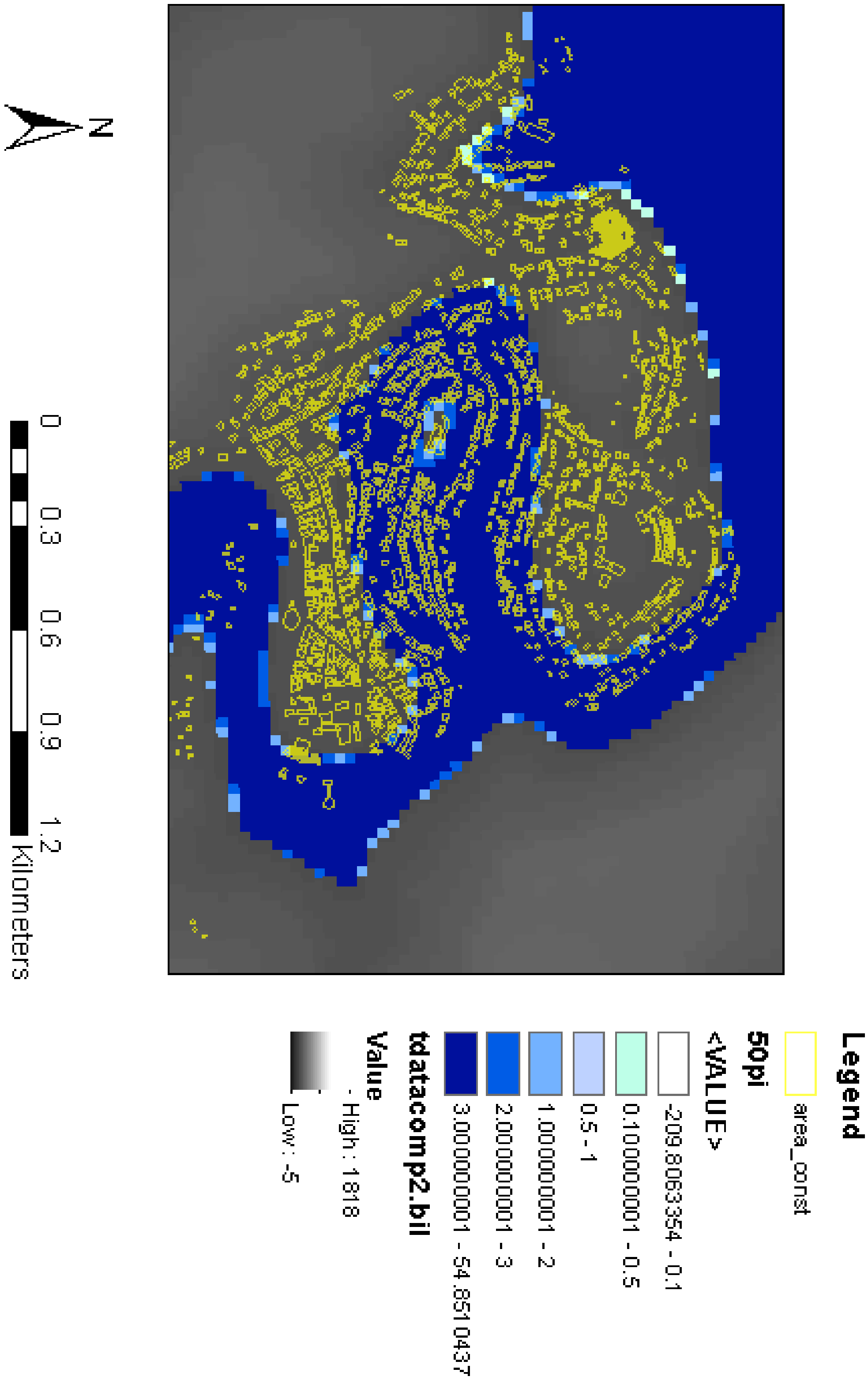
Affected area for 10 year return period flood – view on whole municipality



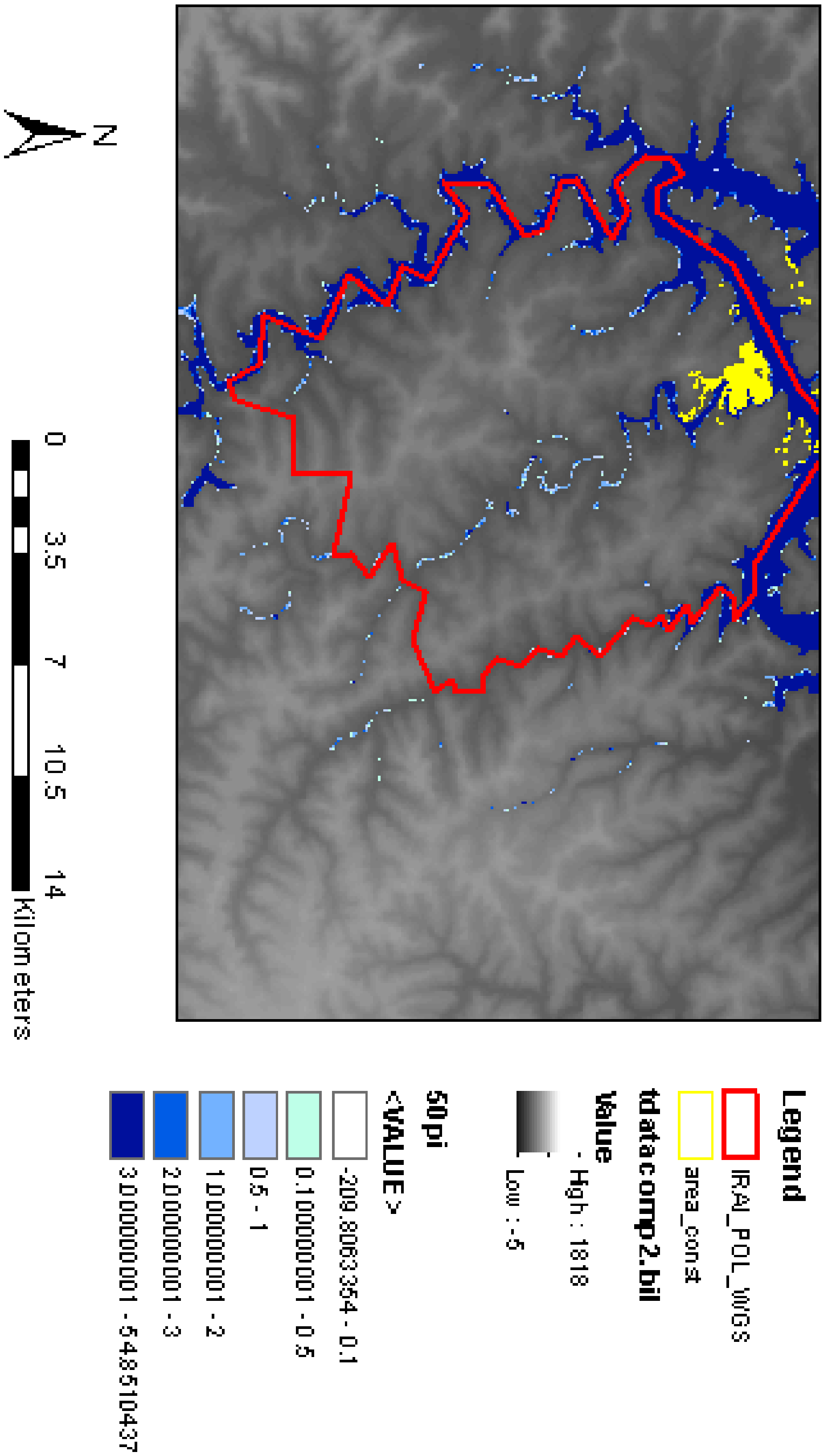
Affected area for 25 year return period flood – view on urban center



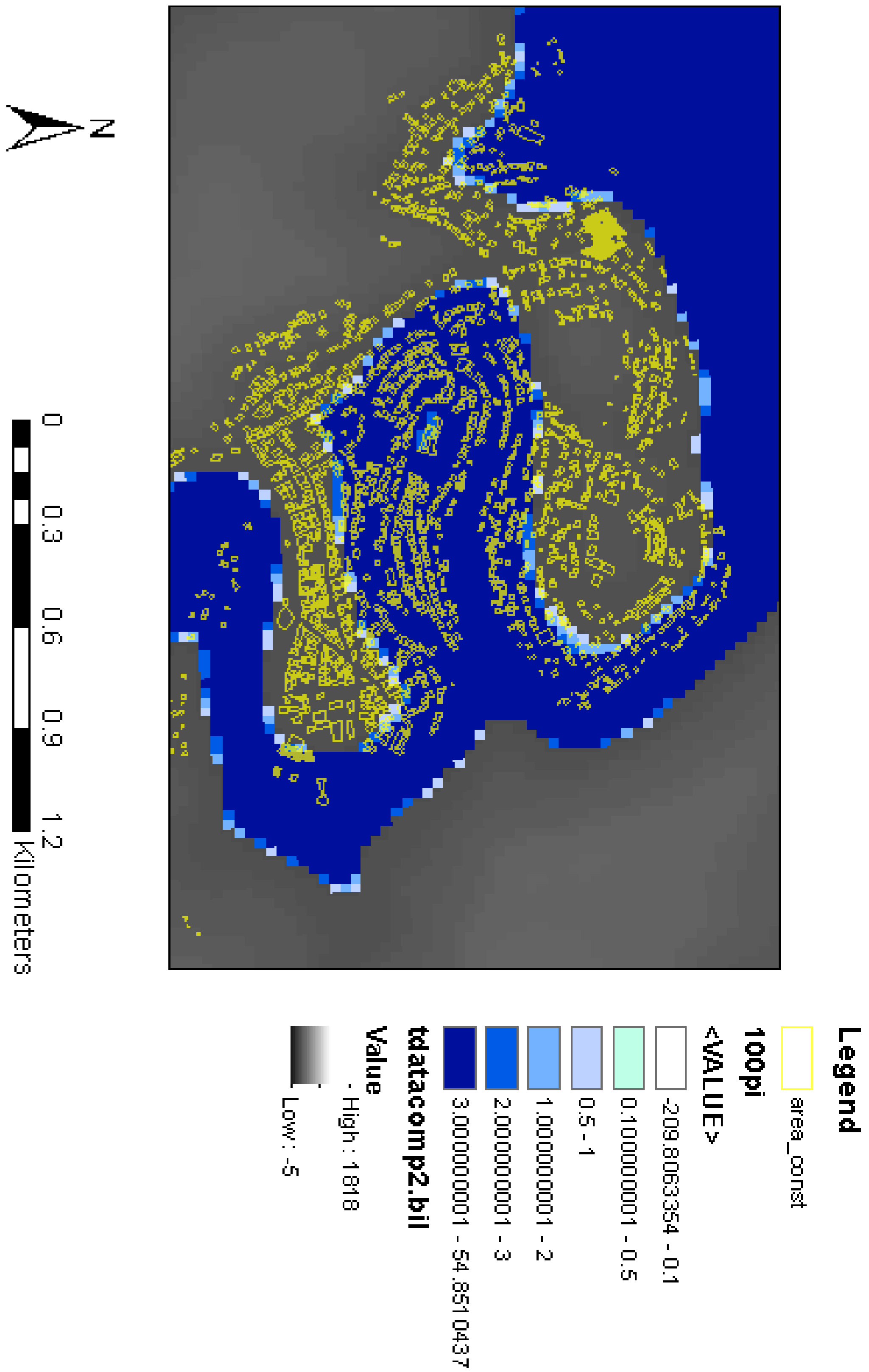
Affected area for 25 year return period flood – view on whole municipality



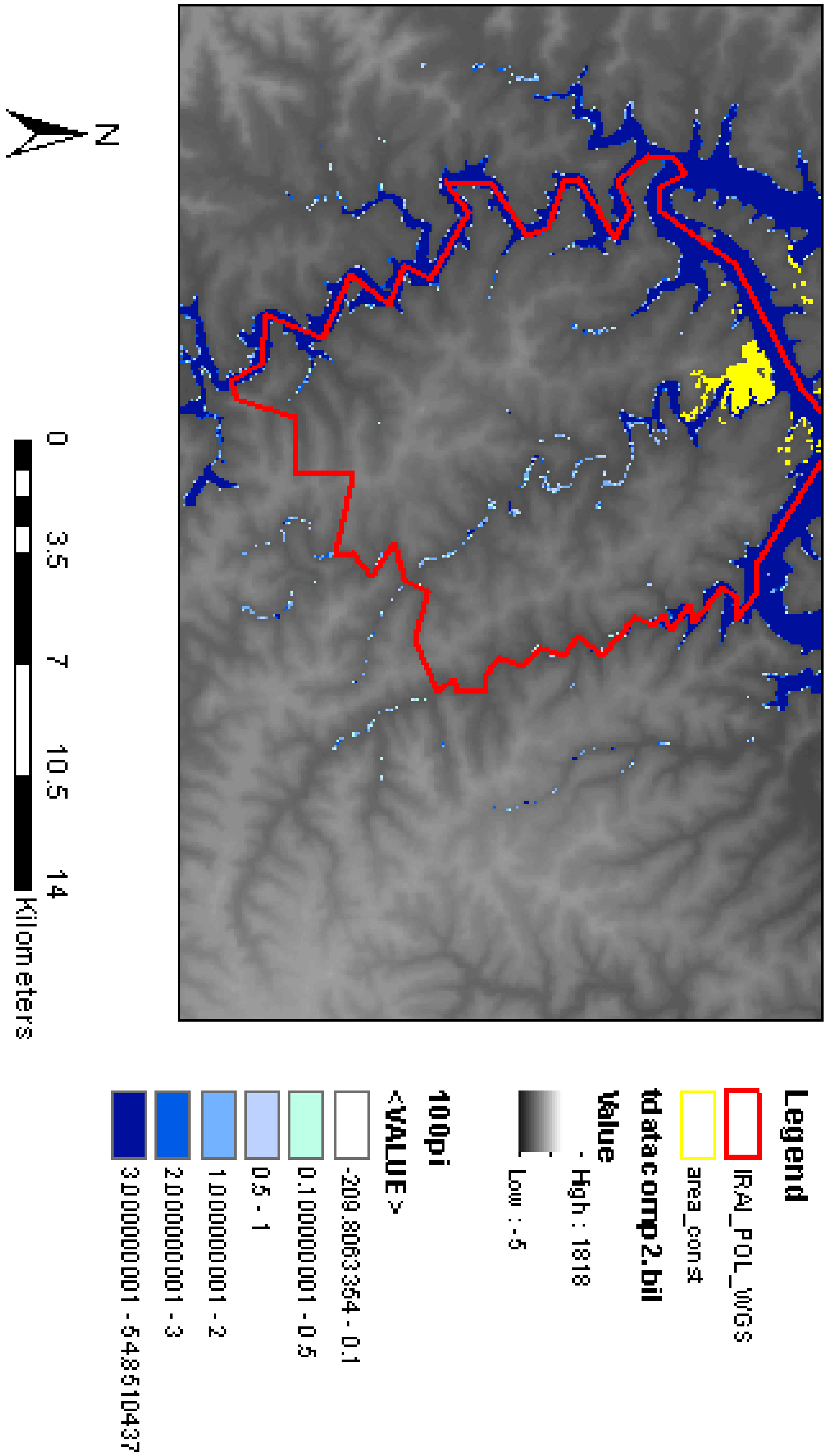
Affected area for 50 year return period flood – view on urban center



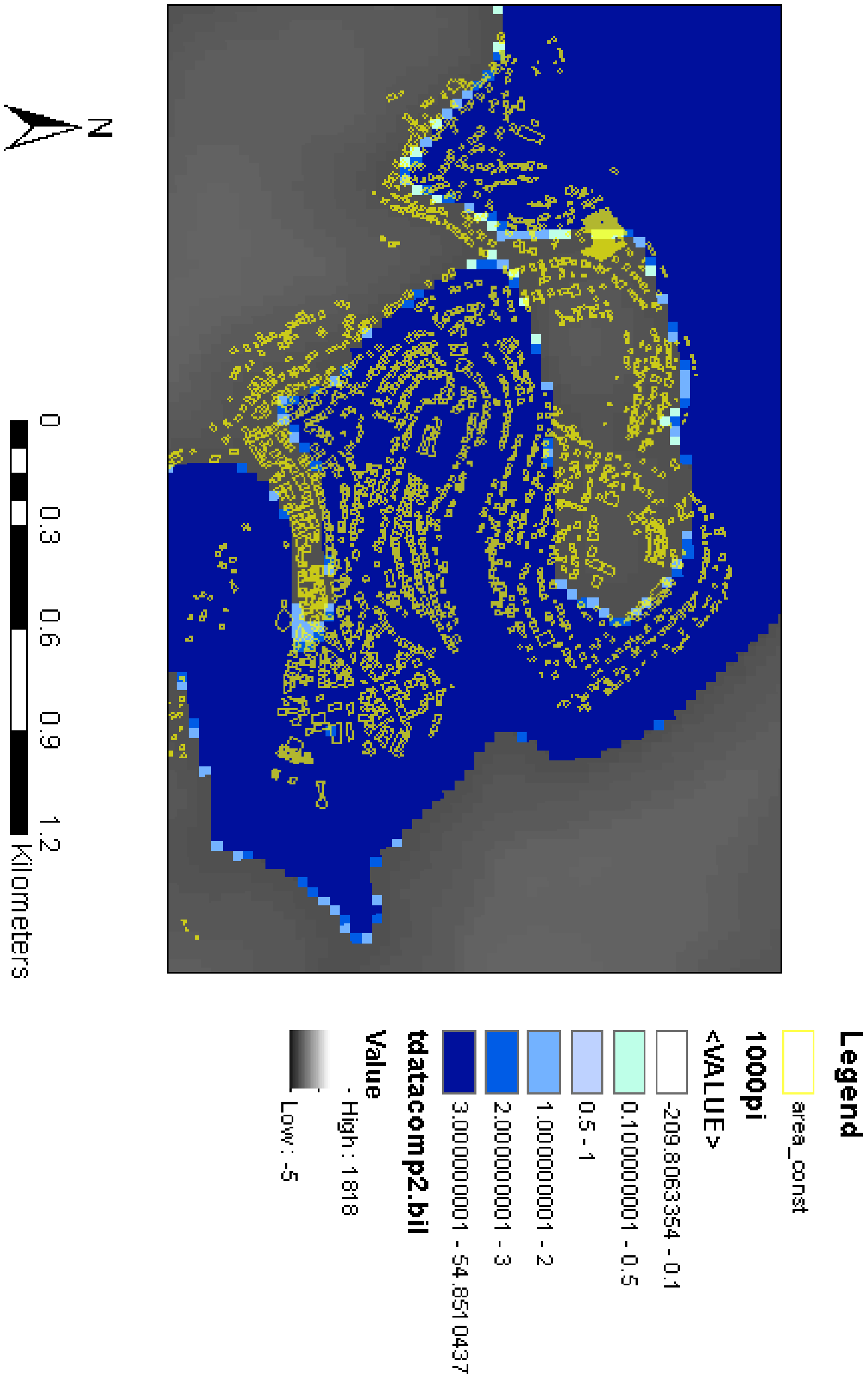
Affected area for 50 year return period flood – view on whole municipality



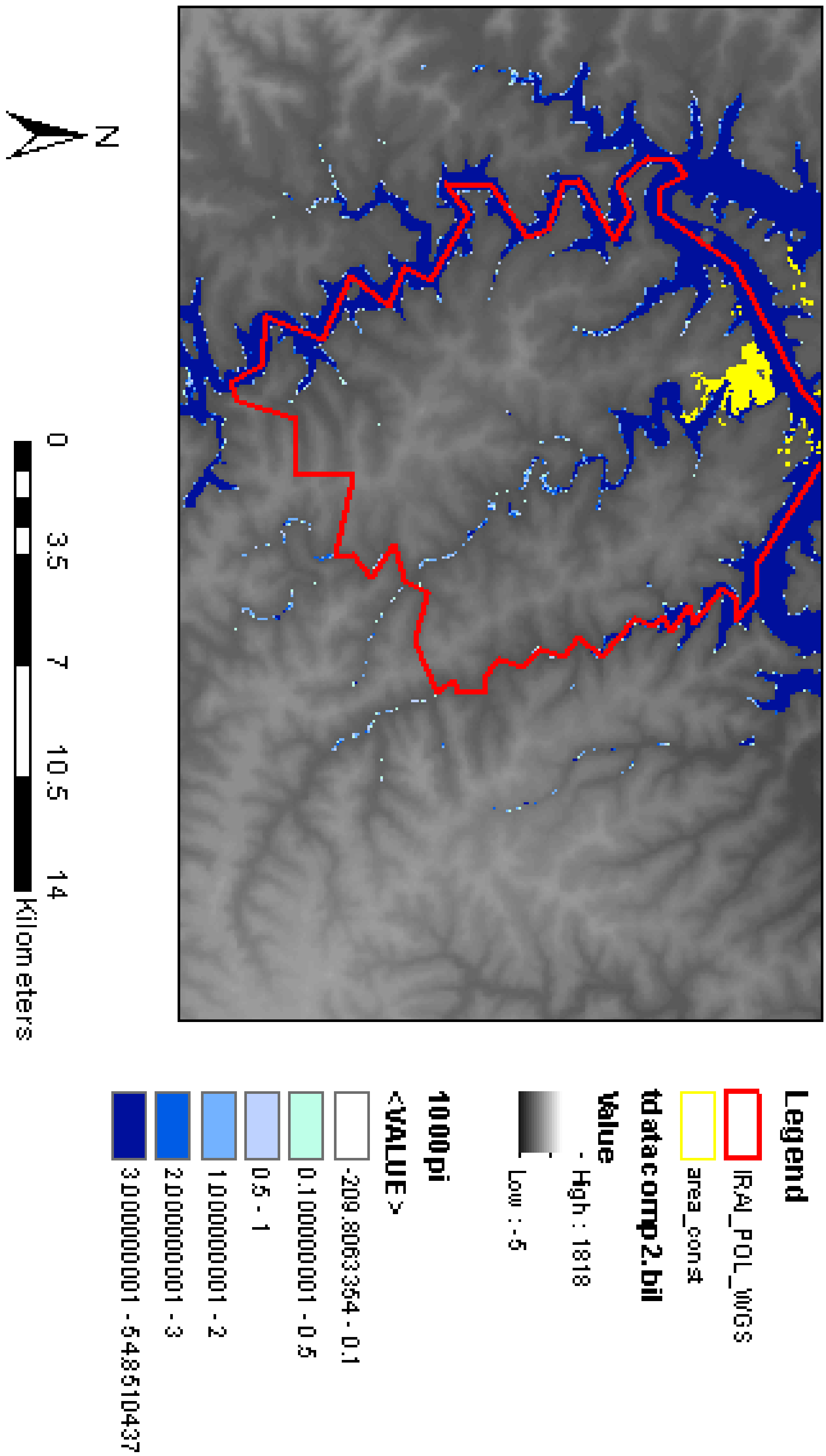
Affected area for 100 year return period flood – view on urban center



Affected area for 100 year return period flood – view on whole municipality



Affected area for 1000 year return period flood – view on urban center



Affected area for 100 year return period flood – view on whole municipality

A. 4 Inventory of Damage - DNOS (1968 *apud* VAZ, 2015), parameters and results of calculation

Modified from VAZ (2015), originally gathered by DNOS (1968) - free translation								Extracted parameters							Observed Damage (% of Monthly Revenue)	Calculated using equation (% of Monthly Revenue)
Activity	Number of Establishments	Number of Employees	Revenue corrected to 2014 values (R$)	Value Added corrected to 2014 values (R$)	Damages corrected to 2014 valuesv (R$)	Monthly Revenue (Revenue / 12)	Damage / Monthly Revenue	LN of (100*DMG/Revenue)	Value Added per Employee	LN Value added	Revenue / Employee	LN Revenue / employee	LN-DMG		
Industrial & Services Activities															
Preparing of stone for masonry	1	25	2051930	1138812	47707	170994	0.28	3.33	45552	10.73	82077	11.32	3.52	27.90	33.94
Ceramics factory	1	19	828227	443101	36348	69019	0.53	3.96	23321	10.06	43591	10.68	4.20	52.66	66.72
Cement and plaster artifacts	4	39	939561	511672	74968	78297	0.96	4.56	13120	9.48	24091	10.09	4.81	95.75	122.32
Metallurgic Industries	19	620	53284789	19425981	615446	4440399	0.14	2.63	31332	10.35	85943	11.36	3.70	13.86	40.25
Mechanics industry	8	726	86420916	33704120	637909	7201743	0.09	2.18	46424	10.75	119037	11.69	3.32	8.86	27.71
Electrical components	2	92	5912795	2128597	221142	492733	0.45	3.80	23137	10.05	64270	11.07	4.00	44.88	54.77
Electrical machines	7	1333	184106754	78429466	2631019	15342229	0.17	2.84	58837	10.98	138115	11.84	3.12	17.15	22.69
Industrial and electrical machinery	1	48	3531360	1246566	96395	294280	0.33	3.49	25970	10.16	73570	11.21	3.87	32.76	48.09
Communications equipment	4	258	33911068	10139394	589711	2825922	0.21	3.04	39300	10.58	131438	11.79	3.36	20.87	28.70
Vehicle parts	3	20	1357582	406680	73469	113132	0.65	4.17	20334	9.92	67879	11.13	4.04	64.94	56.93
Wood industry	7	117	23856247	9470917	246858	1988021	0.12	2.52	80948	11.30	203900	12.23	2.75	12.42	15.71
Furnitures Industry	2	109	7087874	3118664	300308	590656	0.51	3.93	28612	10.26	65026	11.08	3.89	50.84	48.76
Wooden residential furniture	8	239	14165552	6341875	564467	1180463	0.48	3.87	26535	10.19	59270	10.99	3.97	47.82	53.20
Office wooden furniture	6	507	36346543	15992469	1259624	3028879	0.42	3.73	31543	10.36	71689	11.18	3.79	41.59	44.06
Metallic furniture	1	50	3194932	1268384	105664	266244	0.40	3.68	25368	10.14	63899	11.07	3.96	39.69	52.37
Paper and Cardboard Industry	2	25	3973516	1235762	47162	331126	0.14	2.66	49430	10.81	158941	11.98	3.14	14.24	23.09
Rubber Industry	2	21	2204292	839831	32441	183691	0.18	2.87	39992	10.60	104966	11.56	3.46	17.66	31.96
Leather, pelts and similar	2	95	19422273	5146896	565576	1618523	0.35	3.55	54178	10.90	204445	12.23	2.96	34.94	19.32

Pure chemical products	1	6	1530163	615118	9033	127514	0.07	1.96	102520	11.54	255027	12.45	2.52	7.08	12.37
Cleaning products and dedetization	1	54	5459744	1506882	442592	454979	0.97	4.58	27905	10.24	101106	11.52	3.67	97.28	39.28
Oil derivates	1	7	868755	123356	36130	72396	0.50	3.91	17622	9.78	124108	11.73	3.80	49.91	44.84
Industry of pharmacy and medicines	1	9	127218	44781	17938	10602	1.69	5.13	4976	8.51	14135	9.56	5.59	169.20	266.78
Fabrication of diverse chemical products	1	41	49555359	10406625	307105	4129613	0.07	2.01	253820	12.44	1208667	14.01	1.24	7.44	3.45
Industry of plastic products and materials	1	6	1090442	384926	14212	90870	0.16	2.75	64154	11.07	181740	12.11	2.93	15.64	18.81
Textile Industry	4	2579	253967444	72888648	4745450	21163954	0.22	3.11	28262	10.25	98475	11.50	3.68	22.42	39.56
Clothes and Coats production	4	163	188382287	64615119	963815	15698524	0.06	1.81	396412	12.89	1155720	13.96	1.03	6.14	2.80
Production of shoes	2	92	11259105	3895641	494879	938259	0.53	3.97	42344	10.65	122382	11.71	3.36	52.74	28.65
Cereal processing	3	51	3962512	1188745	232264	330209	0.70	4.25	23309	10.06	77696	11.26	3.90	70.34	49.45
Coffee toasting and grinding	2	24	2298325	698873	56776	191527	0.30	3.39	29120	10.28	95764	11.47	3.68	29.64	39.52
Wheat grinding	2	274	40066686	12019998	1001317	3338891	0.30	3.40	43869	10.69	146229	11.89	3.24	29.99	25.65
Production of diversified flour	1	258	79770837	23932078	521304	6647570	0.08	2.06	92760	11.44	309189	12.64	2.47	7.84	11.79
Production of milk derivates	1	6	1090442	201732	20646	90870	0.23	3.12	33622	10.42	181740	12.11	3.27	22.72	26.31
Production of candies, caramels and chocolate	1	656	90192610	22999114	1403908	7516051	0.19	2.93	35060	10.46	137489	11.83	3.39	18.68	29.75
Production of pasta	1	13	896180	219497	51614	74682	0.69	4.24	16884	9.73	68937	11.14	4.13	69.11	62.19
Vegetable oils and fats refining	1	21	7611513	1164556	30969	634293	0.05	1.59	55455	10.92	362453	12.80	2.65	4.88	14.18
Kitchen salt grinding	2	49	18217871	2787324	170327	1518156	0.11	2.42	56884	10.95	371793	12.83	2.63	11.22	13.81
Production of ferments and levedures	2	97	16761803	3668720	335493	1396817	0.24	3.18	37822	10.54	172802	12.06	3.23	24.02	25.40
Production of animal food	1	60	25963563	7789064	268394	2163630	0.12	2.52	129818	11.77	432726	12.98	2.12	12.40	8.32
Graphics and editing industry	4	6	435786	217016	5052	36316	0.14	2.63	36169	10.50	72631	11.19	3.71	13.91	40.76
Scholar material production	1	30	2235406	1108762	61637	186284	0.33	3.50	36959	10.52	74514	11.22	3.68	33.09	39.78

Barber shops	13	20	667314	248221	69788	55610	1.25	4.83	12411	9.43	33366	10.42	4.67	125.50	106.32
Beauty Salons	5	6	82692	28933	20936	6891	3.04	5.72	4822	8.48	13782	9.53	5.62	303.82	274.74
Laundry and dry cleaning	7	21	159423	55785	73278	13285	5.52	6.31	2656	7.88	7592	8.93	6.23	551.57	510.12
Other commerce support	40	151	9765700	4259476	526902	813808	0.65	4.17	28208	10.25	64674	11.08	3.90	64.75	49.26
Night Clubs	4	10	425272	191373	69788	35439	1.97	5.28	19137	9.86	42527	10.66	4.32	196.92	74.88
Cinematographic agencies (film rental)	2	22	6004837	2702170	153534	500403	0.31	3.42	122826	11.72	272947	12.52	2.39	30.68	10.88
Cafes and bar-cafes	3	8	1040182	312048	64990	86682	0.75	4.32	39006	10.57	130023	11.78	3.37	74.98	28.98
Bars	14	37	1388651	421092	300580	115721	2.60	5.56	11381	9.34	37531	10.53	4.65	259.75	104.63
Restaurants and bar-restaurants	29	108	7320801	2196187	877370	610067	1.44	4.97	20335	9.92	67785	11.12	4.04	143.82	56.97
Travel agencies	1	2	24126	7233	16248	2011	8.08	6.69	3617	8.19	12063	9.40	5.83	808.14	341.81
Pensions	12	31	1048106	314420	251838	87342	2.88	5.66	10143	9.22	33810	10.43	4.76	288.33	117.26
Hotels	11	69	3786633	1451106	560542	315553	1.78	5.18	21031	9.95	54879	10.91	4.13	177.64	62.47
Fast foods	6	30	1582359	609730	243714	131863	1.85	5.22	20324	9.92	52745	10.87	4.17	184.82	64.91
Vehicle and bike repair shop	20	124	8805911	4286382	361700	733826	0.49	3.90	34568	10.45	71015	11.17	3.74	49.29	42.22
Electric equipment repair shop	7	19	1354738	518142	55422	112895	0.49	3.89	27271	10.21	71302	11.17	3.86	49.09	47.65
Radio and Electronics repair shops	3	5	243986	60992	14585	20332	0.72	4.27	12198	9.41	48797	10.80	4.48	71.73	88.08
Machine repair shops	2	4	141757	80693	11668	11813	0.99	4.59	20173	9.91	35439	10.48	4.38	98.77	80.09
Other Repair Shops (except Shoes)	4	11	4394482	1098620	32086	366207	0.09	2.17	99875	11.51	399498	12.90	2.30	8.76	9.94
Photography Ateliers	1	2	24989	10041	15103	2082	7.25	6.59	5021	8.52	12495	9.43	5.65	725.24	283.10
Shoe repairing shops	5	5	107727	39011	4453	8977	0.50	3.90	7802	8.96	21545	9.98	5.13	49.60	169.75
Insurancy and titles agencies	1	1	68153	30669	2417	5679	0.43	3.75	30669	10.33	68153	11.13	3.83	42.56	45.90
Tailor	5	8	228602	89780	10541	19050	0.55	4.01	11222	9.33	28575	10.26	4.80	55.33	121.41
Fashionist	22	28	382763	112188	36893	31897	1.16	4.75	4007	8.30	13670	9.52	5.72	115.66	303.75
Cargo transportation offices and agencies	26	505	59707838	21616542	1165001	4975653	0.23	3.15	42805	10.66	118233	11.68	3.37	23.41	29.01
Passanger transportation companies	3	84	24422759	7090791	197697	2035230	0.10	2.27	84414	11.34	290747	12.58	2.55	9.71	12.79
Garages and vehicle service stations	2	24	1286013	703571	56485	107168	0.53	3.96	29315	10.29	53584	10.89	3.97	52.71	53.23

Navigation agencies	2	61	8959454	2687822	143566	746621	0.19	2.96	44063	10.69	146876	11.90	3.24	19.23	25.53
Other service stablishments	6	190	9627731	6548614	447172	802311	0.56	4.02	34466	10.45	50672	10.83	3.92	55.74	50.38
Commercial Activities															
Bazar	2	4	338201	165711	23735	28183	0.84	4.43	41428	10.63	84550	11.35	4.59	84.22	98.70
Food commerce in general	57	550	342341388	67382034	5926662	28528449	0.21	3.03	122513	11.72	622439	13.34	2.68	20.77	14.59
Commerce of integral cereal	12	160	167020390	23395690	2676672	13918366	0.19	2.96	146223	11.89	1043877	13.86	2.16	19.23	8.71
Commerce of gasoline and petrol derivatives	4	32	8970340	1291720	100030	747528	0.13	2.59	40366	10.61	280323	12.54	3.31	13.38	27.36
Commerce of charcoal and petrol in retail	1	4	130126	69788	12504	10844	1.15	4.75	17447	9.77	32532	10.39	5.44	115.31	229.95
Commerce of glass and ceramics	2	62	14215294	7391943	126764	1184608	0.11	2.37	119225	11.69	229279	12.34	3.74	10.70	42.07
Commerce of construction material (except wood)	16	222	103829088	36238117	453897	8652424	0.05	1.66	163235	12.00	467699	13.06	3.04	5.25	20.95
Fruits exportation	1	6	4895903	1302306	25244	407992	0.06	1.82	217051	12.29	815984	13.61	2.51	6.19	12.25
Commerce of fruits in retail	3	5	861222	229075	21036	71769	0.29	3.38	45815	10.73	172244	12.06	3.85	29.31	47.16
Commerce of fruits and other agricultural products in wholesale	2	20	9497533	2526336	84146	791461	0.11	2.36	126317	11.75	474877	13.07	2.97	10.63	19.58
Commerce of eggs, wholesale	2	20	35242661	1057274	112134	2936888	0.04	1.34	52864	10.88	1762133	14.38	1.40	3.82	4.07
Commerce of meat, retail	15	55	36091989	4490368	308368	3007666	0.10	2.33	81643	11.31	656218	13.39	2.54	10.25	12.71
Commerce of milk derivates in general	1	12	829754	570119	67280	69146	0.97	4.58	47510	10.77	69146	11.14	4.83	97.30	125.68
Commerce of parfums and cleaning products	2	85	36770125	13254369	733777	3064177	0.24	3.18	155934	11.96	432590	12.98	3.12	23.95	22.56
Commerce of pharmaceutical products, retail	3	13	1230882	433260	112225	102573	1.09	4.70	33328	10.41	94683	11.46	4.43	109.41	83.76
Commerce of chemical and pharmaceutical products, wholesale	12	280	158007868	55618726	2417147	13167322	0.18	2.91	198638	12.20	564314	13.24	2.88	18.36	17.83

Commerce of photographic and optical material	3	9	3090885	1242532	77694	257574	0.30	3.41	138059	11.84	343432	12.75	3.34	30.16	28.16
Commerce of rubber and plastic products	1	23	8260126	3031465	198551	688344	0.29	3.36	131803	11.79	359136	12.79	3.28	28.84	26.60
Commerce of paints and lacquer	1	18	4047948	1242713	155388	337329	0.46	3.83	69040	11.14	224886	12.32	3.65	46.06	38.51
Commerce of other unspescified products	4	36	14500590	3656062	258980	1208382	0.21	3.06	101557	11.53	402794	12.91	3.11	21.43	22.34
Commerce of wood	6	55	34227596	8473444	706198	2852300	0.25	3.21	154063	11.95	622320	13.34	2.73	24.76	15.27
Commerce of wooden planks and parquet	3	21	7596510	3015808	269639	633043	0.43	3.75	143610	11.87	361739	12.80	3.29	42.59	26.85
Commerce of furniture	2	5	1908274	839640	64200	159023	0.40	3.70	167928	12.03	381655	12.85	3.26	40.37	26.16
Commerce of metal pieces	5	86	23870223	7385137	779139	1989185	0.39	3.67	85874	11.36	277561	12.53	3.47	39.17	32.14
Commerce of electrical material	6	227	132552614	48247828	2056565	11046051	0.19	2.92	212545	12.27	583932	13.28	2.86	18.62	17.43
Commerce of vehicles and acessories	12	424	108707654	38808598	3814337	9058971	0.42	3.74	91530	11.42	256386	12.45	3.57	42.11	35.43
Commerce of industrial machinery	10	102	48924566	19080556	924095	4077047	0.23	3.12	187064	12.14	479653	13.08	3.04	22.67	20.95
Commerce of office material and domestic utensils	2	29	3424661	1541095	262733	285388	0.92	4.52	53141	10.88	118092	11.68	4.29	92.06	72.64
Commerce of iron and other metals	11	139	185438547	54148029	1259306	15453212	0.08	2.10	389554	12.87	1334090	14.10	2.10	8.15	8.15
Commerce of jewelery and bijoux	1	5	590656	278199	45299	49221	0.92	4.52	55640	10.93	118131	11.68	4.29	92.03	73.28
Commerce of naval products	1	1	63609	22708	9060	5301	1.71	5.14	22708	10.03	63609	11.06	4.78	170.91	118.58
Commerce of optical,photographic, etc	1	8	2091922	690332	72478	174327	0.42	3.73	86291	11.37	261490	12.47	3.53	41.58	34.28
Commerce of agropecuary material	3	46	12848607	4368520	416749	1070717	0.39	3.66	94968	11.46	279318	12.54	3.48	38.92	32.57
Commerce of hunting, fishery and sports material	1	1	453778	225067	9060	37815	0.24	3.18	225067	12.32	453778	13.03	3.14	23.96	23.06
Commerce of paper, wholesale	1	129	59414555	18477923	2506218	4951213	0.51	3.92	143240	11.87	460578	13.04	3.03	50.62	20.74

Commerce of journals and magazines	1	2	86327	42991	38856	7194	5.40	6.29	21495	9.98	43163	10.67	5.18	540.13	177.33
Commerce of Shoes	6	22	3405360	1178241	202604	283780	0.71	4.27	53556	10.89	154789	11.95	4.00	71.39	54.52
Commerce of leather	5	28	6176864	1636863	256726	514739	0.50	3.91	58459	10.98	220602	12.30	3.64	49.88	38.03
Commerce of leather products	1	2	994183	263451	18338	82849	0.22	3.10	131725	11.79	497092	13.12	2.93	22.13	18.81
Commerce of textiles products in general	4	139	41504253	11911699	1199941	3458688	0.35	3.55	85696	11.36	298592	12.61	3.39	34.69	29.72
Commerce of manufactored products in general	7	21	8506621	2921431	181286	708885	0.26	3.24	139116	11.84	405077	12.91	3.16	25.57	23.65
Armarinho Stores(school material, costumes, sewing, etc)	3	4	288894	107990	34531	24075	1.43	4.97	26998	10.20	72224	11.19	4.67	143.43	107.19
Commerce of wine, wholesale	4	75	20449569	5089666	226267	1704131	0.13	2.59	67862	11.13	272661	12.52	3.44	13.28	31.26
Commerce of other drinks	6	49	5819208	2129815	147828	484934	0.30	3.42	43466	10.68	118759	11.68	4.24	30.48	69.37

A.5 Table – Comparison and validation of the results of the application of data assimilation and Locational Quotient for the Rio Grande do Sul State

<table>
<tr><th colspan="6">Modified from BRENE (2013) - free translation</th><th colspan="2">Present Study</th></tr>
<tr><th>Classification - BRENE (2013)</th><th>QL - BRENE - 2013</th><th>National Production (IBGE apud BRENE)</th><th>Value Calculated (BRENE 2013)</th><th>After Correction (BRENE)</th><th>Measured FEE (Apud BRENE 2013)</th><th>Integrated Classification from taxes and Industry Relations Table</th><th>QL - Calculated</th></tr>
<tr><td rowspan="3">Agriculture and livestock</td><td rowspan="3">6.51%</td><td rowspan="3">183859</td><td rowspan="3">11975</td><td rowspan="3">21555</td><td rowspan="3">26847</td><td>Agriculture, livestock and related services</td><td>11.33%</td></tr>
<tr><td>Forestry &</td><td rowspan="2">4.88%</td></tr>
<tr><td>Fishery and aquiculture</td></tr>
<tr><td>Mineral extraction</td><td>2.22%</td><td>23250</td><td>516</td><td>516</td><td>384</td><td>Extraction of mineral coal &</td><td rowspan="3">1.93%</td></tr>
<tr><td>Extraction of oil and gas</td><td>0.00%</td><td>44241</td><td>2</td><td>2</td><td>109</td><td>Extraction of petrol and natural gas &</td></tr>
<tr><td>Extraction of non-metallic minerals</td><td>4.97%</td><td>30186</td><td>1499</td><td>1499</td><td>1493</td><td>Extraction of metallic minerals &</td></tr>
</table>

						Extraction of non-metallic minerals &	
						Mining support activities	
Production of aliment, drinks and tobacco	9.63%	216028	20800	28288	36147	Production of aliments	10.06%
						Production of drinks	11.26%
						Production of tobacco products	58.42%
Production of textiles	3.62%	29584	1072	1457	1435	Production of textile products	4.63%
Production of clothing and Accessories	3.43%	22164	760	1033	1268	Production of clothing and accessories	5.17%
Production of shoes and leather products	51.57%	20880	10769	14645	9793	Preparation of leather and production of leather products	52.27%
						Production of wooden products	11.91%
Production of cellulose and paper products	5.82%	58003	3374	4589	2955	Production of cellulose and paper products	6.79%
						Printing and recording	8.06%
Production of pet coke and oil refinement	4.77%	135174	6454	8777	25548	Production of pet coke, petrol derivatives and bio combustibles	3.72%
Production of chemicals	5.03%	102443	5150	7004	9658	Production of chemical products	8.35%
						Production of pharmacochemical and pharmaceutical products	2.38%
Production of rubber and plastic products	9.50%	36510	3470	4719	4418	Production of rubber and plastic materials	11.83%
						Production of non-metallic products	8.55%
Basic metallurgy	5.07%	48441	2455	2455	2282		
Metallurgy of non-ferrous metals	4.69%	18142	852	852	184	Metallurgy	6.76%
	11.71%	36079	4223	4223	4168		

Other metallurgic products						Production of metal products. Except for machines and equipment	16.48%
Production of electronic equipment	6.60%	40324	2663	3622	1819	Production of informatics and electronic and optical products	13.49%
Production of electrical material	6.71%	28926	1941	2639	1977	Production of machinery. Electrical machinery and equipment	7.78%
Production of machines and equipment	13.14%	48374	6354	8642	10493	Production of machinery and equipment	19.52%
Production of automobile vehicles	7.25%	49372	3579	4867	5267	Production of vehicles, tow cars and truck cargos	11.52%
Production of vehicle parts	0.44%	51556	228	310	5389	Production of other transportation equipment. Except for vehicles.	2.17%
Production of wood, furniture and diverse products	11.39%	43679	4975	6765	5259	Production of furniture&	19.32%
						Production of diverse products	
Public utility services	6.50%	102704	6675	6675	5083	Maintenance and repair of machines and equipment	6.73%
						Electricity, gas and other utility	6.42%
						Water supply and treatment of water &	6.15%
						Sewage and related activities&	
						Residues and garbage collection and disposal &	
						Decontamination of residues and other residue management activities	
Civil Construction	6.20%	134543	8344	8344	7459	Civil Construction &	4.72%
						Infrastructure works &	

						Specialized services for construction	
Commerce	7.33%	224885	16491	25265	20510	Commerce and repairing of vehicles and motorbikes	5.42%
						Wholesale commerce. Except for vehicles and motorbikes	
						Retail commerce	
Transportation	7.03%	142281	9998	9998	10661	Ground transportation	5.60%
						Water transportation	1.65%
						Aerial Transportation	1.33%
						Storage and transport support activities	4.75%
Communication and post offices	5.10%	104758	5345	5345	5293	Post offices and other delivery activities	
Services to families	8.21%	203489	16714	16714	14425	Lodging	4.95%
						Alimentation	5.47%
Services to companies *	4.25%	117155	4983	7524	6256	Editing and Printing	5.72%
						Cinematographic activities. Production of video and television programs	4.20%
						Radio and television activities	
						Telecomunications	2.81%
						Information Technology activities	3.61%
						Information provider services	
Financial Institutions	6.67%	164108	10942	10942	9125	Financial services activities	5.15%
						Health Insurance. Re-insurance. Supplementary retirement funds and Healthcare plans	

						Financial activities auxiliary services. Insurances. Supplementary retirement funds.	
Real State Activities	4.41%	150157	6619	9995	16932	Real State Activities	5.34%
Services to companies *	4.25%	117155	4983	7524	6256	Judiciary activities. Accounting and auditing.	5.03%
						Company management consulting and activities of company central offices	
						Architecture and engineering services	3.06%
						Research and scientific development	
						Publicity and market research	
						Other professional activities. Technical and scientific .	2.83%
						Veterinarian Services	
						Non Real state rent. Intangible Assets management	2.87%
						Selection and allocation of workforce	2.90%
						Travel Agencies. Tourism operation and reservation services.	
						Security monitoring and investigation.	4.05%
						Building services and landscaping.	
						Office services, administration support and other services provided to companies	

Public Administration	6.72%	331619	22269	22269	21687	Public Administration, Defense and social security	4.55%
						Education	6.21%
						Human Health Activities.	7.77%
						Integrated human health and social assistance provided in private or shared houses.	
						Social assistance services without lodging	
Non mercantile private services	6.24%	49825	3108	3108	2695	Artistic activities. Production of spectacles.	5.09%
						Cultural and environmental heritage activities.	
						Gambling and games exploring activities.	
						Recreation and leisure activities.	
						Association organization activities	
						Repairing and maintenance of informatics and communication equipment and objects.	
						Other private services.	
						Domestic Services	5.30%
						International Organisms and other foreign Institutions	-

A.6 Reclassification of Statistics and Tax data

Industry Relations Table	Tax - RAIS	PNAD	Municipality GDP	Integrated Classification
0191 Agricultura, inclusive o apoio à	AGRICULTURA. PECUÁRIA E SERVIÇOS	AGRICULTURA, PECUÁRIA, PRODUÇÃO FLORESTAL,	Agropecuaria	Agriculture, livestock and related services

agricultura e a pós-colheita	RELACIONADOS	PESCA E AQUICULTURA		
0192 Pecuária, inclusive o apoio à pecuária				Forestry &
0280 Produção florestal; pesca e aquicultura	PRODUÇÃO FLORESTAL			Fishery and acquiculture
	PESCA E AQÜICULTURA			Extraction of mineral coal &
0580 Extração de carvão mineral e de minerais não-metálicos	EXTRAÇÃO DE CARVÃO MINERAL			Extraction of petrol and natural gas &
0680 Extração de petróleo e gás, inclusive as atividades de apoio	EXTRAÇÃO DE PETRÓLEO E GÁS NATURAL			Extraction of metallic minerals &
0791 Extração de minério de ferro, inclusive beneficiamentos e a aglomeração	EXTRAÇÃO DE MINERAIS METÁLICOS			Extraction of non-metallic minerals &
0792 Extração de minerais metálicos não-ferrosos, inclusive beneficiamentos	EXTRAÇÃO DE MINERAIS NÃO-METÁLICOS			Mining support activities
	ATIVIDADES DE APOIO À EXTRAÇÃO DE MINERAIS			Production of aliments
1091 Abate e produtos de carne, inclusive os produtos do laticínio e da pesca				
1092 Fabricação e refino de açúcar				
1093 Outros produtos alimentares	FABRICAÇÃO DE PRODUTOS ALIMENTÍCIOS	INDÚSTRIA GERAL	Industria	

1100 Fabricação de bebidas	FABRICAÇÃO DE BEBIDAS			Production of drinks
1200 Fabricação de produtos do fumo	FABRICAÇÃO DE PRODUTOS DO FUMO			Production of tobacco products
1300 Fabricação de produtos têxteis	FABRICAÇÃO DE PRODUTOS TÊXTEIS			Production of textile products
1400 Confecção de artefatos do vestuário e acessórios	CONFECÇÃO DE ARTIGOS DO VESTUÁRIO E ACESSÓRIOS			Production of clothing and accessories
1500 Fabricação de calçados e de artefatos de couro	PREPARAÇÃO DE COUROS E FABRICAÇÃO DE ARTEFATOS DE COURO. ARTIGOS PARA VIAGEM E CALÇADOS			Preparation of leather and production of leather products
1600 Fabricação de produtos da madeira	FABRICAÇÃO DE PRODUTOS DE MADEIRA			Production of wooden products
1700 Fabricação de celulose, papel e produtos de papel	FABRICAÇÃO DE CELULOSE. PAPEL E PRODUTOS DE PAPEL			Production of cellulose and paper products
1800 Impressão e reprodução de gravações	IMPRESSÃO E REPRODUÇÃO DE GRAVAÇÕES			Printing and recording
1991 Refino de petróleo e coquerias	FABRICAÇÃO DE COQUE. DE PRODUTOS DERIVADOS DO PETRÓLEO E DE BIOCOMBUSTÍVEIS			Production of petcoke, petrol derivatives and biocombustibles
1992 Fabricação de biocombustíveis				Production of chemical products
2091 Fabricação de químicos orgânicos e inorgânicos, resinas e elastômeros	FABRICAÇÃO DE PRODUTOS QUÍMICOS			

2092 Fabricação de defensivos, desinfestantes, tintas e químicos diversos				
2093 Fabricação de produtos de limpeza, cosméticos/perfumaria e higiene pessoal				
2100 Fabricação de produtos farmoquímicos e farmacêuticos	FABRICAÇÃO DE PRODUTOS FARMOQUÍMICOS E FARMACÊUTICOS			Production of pharmochemicals and pharmaceutical products
2200 Fabricação de produtos de borracha e de material plástico	FABRICAÇÃO DE PRODUTOS DE BORRACHA E DE MATERIAL PLÁSTICO			Production of rubber and plastic materials
2300 Fabricação de produtos de minerais não-metálicos	FABRICAÇÃO DE PRODUTOS DE MINERAIS NÃO-METÁLICOS			Production of non-metallic products
2491 Produção de ferro-gusa/ferroligas, siderurgia e tubos de aço sem costura				Metallurgy
2492 Metalurgia de metais não-ferosos e a fundição de metais	METALURGIA			
2500 Fabricação de produtos de metal, exceto máquinas e equipamentos	FABRICAÇÃO DE PRODUTOS DE METAL. EXCETO MÁQUINAS E EQUIPAMENTOS			Production of metal products. Except for machines and equipment
2600 Fabricação de equipamentos de informática,	FABRICAÇÃO DE EQUIPAMENTOS DE			Production of informatic and electronicand optical products

produtos eletrônicos e ópticos	INFORMÁTICA. PRODUTOS ELETRÔNICOS E ÓPTICOS			
2700 Fabricação de máquinas e equipamentos elétricos	FABRICAÇÃO DE MÁQUINAS. APARELHOS E MATERIAIS ELÉTRICOS			Production of machinery. Electrical machinery and equipment
2800 Fabricação de máquinas e equipamentos mecânicos	FABRICAÇÃO DE MÁQUINAS E EQUIPAMENTOS			Production of machinery and equipment
2991 Fabricação de automóveis, caminhões e ônibus, exceto peças	FABRICAÇÃO DE VEÍCULOS AUTOMOTORES. REBOQUES E CARROCERIAS			Production of vehicles, tow cars and truck cargos
2992 Fabricação de peças e acessórios para veículos automotores				
3000 Fabricação de outros equipamentos de transporte, exceto veículos automotores	FABRICAÇÃO DE OUTROS EQUIPAMENTOS DE TRANSPORTE. EXCETO VEÍCULOS AUTOMOTORES			Production of other transportation equipment. Except for vehicles.
3180 Fabricação de móveis e de produtos de indústrias diversas	FABRICAÇÃO DE MÓVEIS			Production of furniture&
	FABRICAÇÃO DE PRODUTOS DIVERSOS			Production of diverse products
3300 Manutenção, reparação e instalação de máquinas e equipamentos	MANUTENÇÃO. REPARAÇÃO E INSTALAÇÃO DE MÁQUINAS E EQUIPAMENTOS			Maintenance and repair of machines and equipment
3500 Energia elétrica, gás natural e outras utilidades	ELETRICIDADE. GÁS E OUTRAS UTILIDADES			Electricity, gas and other utility

3680 Água, esgoto e gestão de resíduos	CAPTAÇÃO. TRATAMENTO E DISTRIBUIÇÃO DE ÁGUA			Water Supply and treatment of water &
	ESGOTO E ATIVIDADES RELACIONADAS			Sewage and related activities&
	COLETA. TRATAMENTO E DISPOSIÇÃO DE RESÍDUOS			Residues and garbage collection and disposal &
	DESCONTAMINAÇÃO E OUTROS SERVIÇOS DE GESTÃO DE RESÍDUOS			Decontamination of residues and other residue management activities
4180 Construção	CONSTRUÇÃO DE EDIFÍCIOS	CONSTRUÇÃO		Civil Construction &
	OBRAS DE INFRA-ESTRUTURA			Infrastructure works &
	SERVIÇOS ESPECIALIZADOS PARA CONSTRUÇÃO			Especialized services for construction
4580 Comércio por atacado e varejo	COMÉRCIO E REPARAÇÃO DE VEÍCULOS AUTOMOTORES E MOTOCICLETAS	COMÉRCIO, REPARAÇÃO DE VEÍCULOS AUTOMOTORES E MOTOCICLETAS	Servicos & Administracao	Commerce and repairing of vehicles and motorbikes
	COMÉRCIO POR ATACADO. EXCETO VEÍCULOS AUTOMOTORES E MOTOCICLETAS			Wholesale commerce. Except for vehicles and motorbikes
	COMÉRCIO VAREJISTA			Retail commerce
4900 Transporte terrestre	TRANSPORTE TERRESTRE	TRANSPORTE, ARMAZENAGEM E CORREIO		Ground transportation
5000 Transporte aquaviário	TRANSPORTE AQUAVIÁRIO			Water transportation
5100 Transporte aéreo	TRANSPORTE AÉREO			Aerial Transportation

5280 Armazenamento, atividades auxiliares dos transportes e correio	ARMAZENAMENTO E ATIVIDADES AUXILIARES DOS TRANSPORTES			Storage and transportat support activities
	CORREIO E OUTRAS ATIVIDADES DE ENTREGA			Post offices and other delivery activities
5500 Alojamento	ALOJAMENTO	ALOJAMENTO E ALIMENTAÇÃO		Lodging
5600 Alimentação	ALIMENTAÇÃO			Alimentation
5800 Edição e edição integrada à impressão	EDIÇÃO E EDIÇÃO INTEGRADA À IMPRESSÃO	INFORMAÇÃO, COMUNICAÇÃO E ATIVIDADES FINANCEIRAS, IMOBILIÁRIAS, PROFISSIONAIS E ADMINISTRATIVAS		Editing and Printing
5980 Atividades de televisão, rádio, cinema e gravação/edição de som e imagem	ATIVIDADES CINEMATOGRÁFICAS. PRODUÇÃO DE VÍDEOS E DE PROGRAMAS DE TELEVISÃO			Cinematographic activities. Production of video and television programs
	ATIVIDADES DE RÁDIO E DE TELEVISÃO			Radio and television activities
6100 Telecomunicações	TELECOMUNICAÇÕES			Telecommunication
6280 Desenvolvimento de sistemas e outros serviços de informação	ATIVIDADES DOS SERVIÇOS DE TECNOLOGIA DA INFORMAÇÃO			Information Technology activities
	ATIVIDADES DE PRESTAÇÃO DE SERVIÇOS DE INFORMAÇÃO			Information provider services
6480 Intermediação financeira, seguros e previdência complementar	ATIVIDADES DE SERVIÇOS FINANCEIROS			Financial services activities
	SEGUROS. RESSEGUROS. PREVIDÊNCIA COMPLEMENTAR E PLANOS DE SAÚDE			Health Insurance. Re-insurance. Supplementary retirement funds and Healthcare plans

	ATIVIDADES AUXILIARES DOS SERVIÇOS FINANCEIROS. SEGUROS. PREVIDÊNCIA COMPLEMENTAR E PLANOS DE SAÚDE			Financial activities auxiliary services. Insurances. Supplementary retirement funds.
6800 Atividades imobiliárias	ATIVIDADES IMOBILIÁRIAS			Real State Activities
6980 Atividades jurídicas, contábeis, consultoria e sedes de empresas	ATIVIDADES JURÍDICAS. DE CONTABILIDADE E DE AUDITORIA			Judiciary activities. Accounting and auditing.
	ATIVIDADES DE SEDES DE EMPRESAS E DE CONSULTORIA EM GESTÃO EMPRESARIAL			Company management consulting and activities of company central offices
7180 Serviços de arquitetura, engenharia, testes/análises técnicas e P & D	SERVIÇOS DE ARQUITETURA E ENGENHARIA			Architecture and engineering services
	PESQUISA E DESENVOLVIMENTO CIENTÍFICO			Research and scientific development
	PUBLICIDADE E PESQUISA DE MERCADO			Publicity and market research
7380 Outras atividades profissionais, científicas e técnicas	OUTRAS ATIVIDADES PROFISSIONAIS. CIENTÍFICAS E TÉCNICAS			Other professional activities. Technical and scientific .
	ATIVIDADES VETERINÁRIAS			Veterinarian Services
7700 Aluguéis não-imobiliários e gestão de ativos de propriedade intelectual	ALUGUÉIS NÃO-IMOBILIÁRIOS E GESTÃO DE ATIVOS INTANGÍVEIS NÃO-FINANCEIROS			Non Real state rent Intangible Assets management
7880 Outras atividades administrativas	SELEÇÃO. AGENCIAMENTO E LOCAÇÃO DE MÃO-DE-OBRA			Selection and allocation of workforce

e serviços complementares	AGÊNCIAS DE VIAGENS. OPERADORES TURÍSTICOS E SERVIÇOS DE RESERVAS			Travel Agencies. Tourism operation and reservation services.
	ATIVIDADES DE VIGILÂNCIA. SEGURANÇA E INVESTIGAÇÃO			Security monitoring and investigation.
	SERVIÇOS PARA EDIFÍCIOS E ATIVIDADES PAISAGÍSTICAS			Building services and landscaping.
8000 Atividades de vigilância, segurança e investigação	SERVIÇOS DE ESCRITÓRIO. DE APOIO ADMINISTRATIVO E OUTROS SERVIÇOS PRESTADOS ÀS EMPRESAS			Office services, administration support and other services provided to companies
8400 Administração pública, defesa e seguridade social	ADMINISTRAÇÃO PÚBLICA. DEFESA E SEGURIDADE SOCIAL			Public Administration, Defense and social security
8591 Educação pública				Education
8592 Educação privada	EDUCAÇÃO			
8691 Saúde pública	ATIVIDADES DE ATENÇÃO À SAÚDE HUMANA			Human Health Activities.
	ATIVIDADES DE ATENÇÃO À SAÚDE HUMANA INTEGRADAS COM ASSISTÊNCIA SOCIAL. PRESTADAS EM RESIDÊNCIAS COLETIVAS E PARTICULARES			Integrated human health and social assistance provided in private or shared houses.
8692 Saúde privada	SERVIÇOS DE ASSISTÊNCIA SOCIAL SEM ALOJAMENTO	ADMINISTRAÇÃO PÚBLICA, DEFESA, SEGURIDADE SOCIAL, EDUCAÇÃO, SAÚDE HUMANA E SERVIÇOS SOCIAIS		Social assistance services without lodging

9080 Atividades artísticas, criativas e de espetáculos	ATIVIDADES ARTÍSTICAS. CRIATIVAS E DE ESPETÁCULOS			Artistic activities. Production of spectacles.
	ATIVIDADES LIGADAS AO PATRIMÔNIO CULTURAL E AMBIENTAL			Cultural and environmental heritage activities.
	ATIVIDADES DE EXPLORAÇÃO DE JOGOS DE AZAR E APOSTAS			Gambling and games exploring activities.
	ATIVIDADES ESPORTIVAS E DE RECREAÇÃO E LAZER			Recreation and leisure activities.
	ATIVIDADES DE ORGANIZAÇÕES ASSOCIATIVAS			Association organization activities
	REPARAÇÃO E MANUTENÇÃO DE EQUIPAMENTOS DE INFORMÁTICA E COMUNICAÇÃO E DE OBJETOS PESSOAIS E DOMÉSTICOS			Repairing and maintenance of informatics and communication equipment and objects.
9480 Organizações associativas e outros serviços pessoais	OUTRAS ATIVIDADES DE SERVIÇOS PESSOAIS	OUTROS SERVIÇOS		Other private services.
9700 Serviços domésticos	SERVIÇOS DOMÉSTICOS			Domestic Services
-	ORGANISMOS INTERNACIONAIS E OUTRAS INSTITUIÇÕES EXTRATERRITORIAIS	SERVIÇOS DOMÉSTICOS		International Organisms and other foreign Institutions

A.7 Table – Parameters and Calculated Maximum Damage for Irai (from 2014 values for parameters as defined in Table 5.1)

Integrated Classification	Number of Employees-Calculated	Average Wage - Calculated	Total Revenue - Calculated	Value Added - Calculated	Maximum Damage (% of Monthly Revenue) Calculated	Maximum Damage - Calculated
Agriculture, livestock and related services	1557.141272	801	35,380,231	20,329,095	115	3,385,565
Forestry &	0	0	0	0	0	0
Fishery and aquiculture	0	-	-	-	-	-
Extraction of mineral coal &	0	0	0	0	0	0
Extraction of petrol and natural gas &	0	-	-	-	-	-
Extraction of metallic minerals &	0	-	-	-	-	-
Extraction of non-metallic minerals &	0	-	-	-	-	-
Mining support activities	0	-	-	-	-	-
Production of aliments	30.33957849	1,014	3,439,174	592,536	35	99,636
Production of drinks	0	0	0	0	0	0
Production of tobacco products	0	0	0	0	0	0
Production of textile products	0	0	0	0	0	0
Production of clothing and accessories	5	1,280	1,003,764	455,940	12	9,717
Preparation of leather and production of leather products	0	0	0	0	0	0

Production of wooden products	3	1,107	638,819	259,455	12	6,165
Production of cellulose and paper products	0	0	0	0	0	0
Printing and recording	0	0	0	0	0	0
Production of pet coke, petrol derivatives and bio combustibles	0	0	0	0	0	0
Production of chemical products	0	0	0	0	0	0
Production of pharmacochemical and pharmaceutical products	0	0	0	0	0	0
Production of rubber and plastic materials	0	0	0	0	0	0
Production of non-metallic products	12.03178012	1,013	1,086,717	378,716	31	27,650
Metallurgy	0	0	0	0	0	0
Production of metal products. Except for machines and equipment	21	1,077	4,064,064	1,574,089	13	44,389
Production of informatics and electronic and optical products	0	0	0	0	0	0
Production of machinery. Electrical machinery and equipment	11	995	2,960,785	739,540	12	28,834
Production of machinery and equipment	0	0	0	0	0	0

Production of vehicles, tow cars and truck cargos	0	0	0	0	0	0
Production of other transportation equipment. Except for vehicles.	0	0	0	0	0	0
Production of furniture&	3	1,148	735,711	341,693	9	5,720
Production of diverse products	0	-	-	-	-	-
Maintenance and repair of machines and equipment	0	0	0	0	0	0
Electricity, gas and other utility	0	0	0	0	0	0
Water supply and treatment of water &	6	3,937	1,629,296	910,356	30	40,677
Sewage and related activities&	0	-	-	-	-	-
Residues and garbage collection and disposal &	0	-	-	-	-	-
Decontamination of residues and other residue management activities	0	-	-	-	-	-
Civil Construction &	140.0581866	1,000	9,231,434	4,272,133	147	1,133,036
Infrastructure works &	0	-	-	-	-	-
Specialized services for construction	82.92167656	-	-	-	-	-
Commerce and repairing of vehicles and motorbikes	23.09682954	973	17,060,286	10,980,748	171	2,430,146
Wholesale commerce.	22.18793791	-	-	-	-	-

Except for vehicles and motorbikes						
Retail commerce	408.2793187	-	0	0	0	0
Ground transportation	71.7757578	1,163	4,180,532	1,836,082	108	377,738
Water transportation	0	0	0	0	0	0
Aerial Transportation	0	0	0	0	0	0
Storage and transport support activities	5	1,694	1,585,786	909,516	124	164,453
Post offices and other delivery activities	25.01678612	-	-	-	-	-
Lodging	54.15918811	1,026	1,456,156	823,213	223	270,390
Alimentation	100.8222096	726	3,061,694	1,503,751	195	497,442
Editing and Printing	0	0	0	0	0	0
Cinematographic activities. Production of video and television programs	0	964	563,185	245,903	72	33,611
Radio and television activities	6	-	-	-	-	-
Telecommunications	0	0	0	0	0	0
Information Technology activities	0	0	0	0	0	0
Information provider services	0	-	-	-	-	-
Financial services activities	79.22071013	3,778	10,876,315	6,734,078	55	500,539
Health Insurance. Re-insurance. Supplementary retirement funds and	0	-	-	-	-	-

Healthcare plans						
Financial activities auxiliary services. Insurances. Supplementary retirement funds.	0	-	-	-	-	-
Real State Activities	0	0	0	0	0	0
Judiciary activities. Accounting and auditing.	43.82582354	1,142	2,837,581	1,934,646	108	255,362
Company management consulting and activities of company central offices	0	-	-	-	-	-
Architecture and engineering services	0	0	0	0	0	0
Research and scientific development	0	-	-	-	-	-
Publicity and market research	0	-	-	-	-	-
Other professional activities. Technical and scientific .	0	0	0	0	0	0
Veterinarian Services	0	-	-	-	-	-
Non Real state rent. Intangible Assets management	0	0	0	0	0	0
Selection and allocation of workforce	0	0	0	0	0	0
Travel Agencies. Tourism	0	-	-	-	-	-

operation and reservation services.						
Security monitoring and investigation.	1	975	122,540	100,379	1,034	105,614
Building services and landscaping.	0	-	-	-	-	-
Office services, administration support and other services provided to companies	23.59784784	-	0	0	0	0
Public Administration, Defense and social security	294.3136405	1,491	8,626,895	6,114,510	216	1,554,937
Education	0.521081866	1,887	57,640	43,720	69	3,331
Human Health Activities.	76.55575982	1,901	17,284,073	10,282,330	50	721,639
Integrated human health and social assistance provided in private or shared houses.	0	-	-	-	-	-
Social assistance services without lodging	37	-	-	-	-	-
Artistic activities. Production of spectacles.	1	1,159	2,980,326	1,453,580	228	566,351
Cultural and environmental heritage activities.	0	-	-	-	-	-
Gambling and games exploring activities.	0	-	-	-	-	-
Recreation and leisure activities.	0	-	-	-	-	-

Association organization activities	104.5492262	-	-	-	-	-
Repairing and maintenance of informatics and communication equipment and objects.	3	-	-	-	-	-
Other private services.	9.229108019	-	-	-	-	-
Domestic Services	221.8622093	-	-	-	-	-
International Organisms and other foreign Institutions	0	-	-	-	-	-

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